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NAVAL POSTGRADUATE SCHOOL

Monterey, California

HP-41CV FLIGHT PERFORMANCE ADVISORY SYSTEM (FPAS)

FOR THE E-2C, E-2B, AND C-2A AIRCRAFT

LCDR Dennis R. Ferrell, USN

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This report describes follow-on work performed under the auspices of AE 4900, Directed Studies in Aeronautical Engineering at the Naval Postgraduate School, to complement the original design of a Flight Performance Advisory System (FPAS) for the E-2C aircraft. The original design fulfilled the requirements of AE 3001, Aircraft Energy Conservation.

AE 3001, offered in the Fall Quarter 1981, and conducted by Professor Allen E. Fuhs, was sponsored in part by the Naval Air Development Center.

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(NADC). NADC desired to obtain the input of several fleet experienced aviators in order to design program code for the HP-41CV handheld, programmable calculator that would benefit pilots by providing them with fuel efficiency parameters in flight. Calculators were made available to the participants with the proviso that a completed and operable code for each aircraft be submitted by the end of the academic quarter, September 1981.

Upon completion of the E-2C program, attempts were made to use the calculator in flight. One test was conducted informally in an E-2C at RVAW-110, NAS Miramar. Unfortunately, the voltage field induced in the cockpit by the main lobe of the radar passing over the cockpit caused the calculator to cease functioning.

The need to devise shielding for the calculator, plus the desire to simplify and improve the existing code lead to this effort. Concurrently, a decision was made to modify a program designed for the E-2B by another officer and to create a program for the C-2A. Since all three aircraft are similar in performance characteristics, an attempt has been made to standardize code format. All programming efforts were sponsored by NADC.

Upon special request from NADC, a kneeboard was also designed to incorporate the HP-41CV in a compact arrangement to enhance its utility and prevent additional loose items in the cockpit. Photographs and construction details are included.

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FLIGHT PERFORMANCE ADVISORY SYSTEMS

For many years, NADC has been concerned with developing technologies to enhance the performance of Naval aircraft in all phases of flight by improving hardware and capabilities. One of their most current and urgent efforts is the improvement of fuel consumption characteristics for Naval aircraft. Specifically, there are six aircraft that represent the greatest percentage of fuel consummed. They are the F-4, P-3, A-6, A-7, A-4 and the F-14. Some of the methods considered to improve the fuel consumption characteristics of these aircraft include engine modifications, changing operational characteristics, and the design of computer software that assists the pilot in determining the most efficient fuel consumption profile to fly at any given moment during a flight.

The design of fuel efficiency software falls within a classification called Flight Performance Advisory Systems (FPAS). Since the hardware/software on-board capabilities of most military aircraft are committed to operational considerations, handheld programmable calculators have been pressed into service in the cockpit to provide easily accessible flight performance parameters.

1.1 BACKGROUND

NADC has set a goal to reduce fuel consumption in Naval aircraft by five percent through the application of advanced technologies. The motivation for such a goal is obvious: the 1973 oil embargo by Arab nations and subsequent incidents sent the cost of fuel skyrocketing and has reduced supplies on more than one occassion. Methods must be found to minimize reliance on foreign sources by reducing fuel consumption rates without affecting training and operational capability.

Opportunities exist in the operational profile of any aircraft to reduce fuel consumption rates by providing the pilot with a method of determining optimal configurations for maximum range and maximum endurance. Currently, the only information available to pilots exists in the NATOPS Manuals. This information, however, is very limited in utility because of the bulk of material and its complexity. The use of information in NATOPS is generally limited to ready-room research, a practice hardly condusive to enhancement of real-time performance.

1.1.1 Handheld Programmable Calculators

Inexpensive calculators have been available in the US market now for 10 to 15 years. The most recent additions to this market are programmable calculators, those capable of taking a set of input parameters and computing a numerical response with an infinite variety and complexity of equations.

By manipulating the data in the NATOPS Manual, equations can be programmed to return answers to such questions as what is the correct airspeed to fly max range corrected for temperature, altitude and winds.

NADC used the most current ideas in the design of such programs by formulating a code for the A-7[1] to be used with the HP-41CV, an advanced technology calculator manufactured by Hewlett-Packard. This program served as a prototype for the efforts which were sponsored by NADC at the Naval Postgraduate School.

1.1.2 FPAS Program Designs

AE3001, Aircraft Energy Conservation, is a course offered by the Aeronautical Engineering Department at the Naval Postgraduate School at least once each year to interested students. When offered in the Summer Quarter, 1981, NADC sponsored the use of the HP-41CV calculator to participating students who agreed to design programs for their aircraft. Primary emphasis was placed on programs for the six major fuel consuming aircraft previously mentioned, but program designs for other aircraft were given consideration as well.

Few restrictions were placed on the design of these programs. The A-7 code designed by NADC was made available as a reference, and lecture material provided background on the

[1] The work which lead to the development of this program was originally performed by officers/engineers attached to A-7 squadrons at NAS Lemoore. Their intent was to use regression analysis on NATOPS data to devise simple equations that could be used in a programmable calculator to provide pilots with mission planning data.

need for programs. NADC hoped to learn what fleet experienced aviators really wanted to see in the cockpit, thereby avoiding needless duplication of effort and the presentation of parameters of limited utility.

Aircraft for which final code were submitted include the F-14, S-3, SH-3, A-6, EA-6B, E-2B, E-2C, A-4, and the F-4. This author designed the program for the E-2C.

1.2 THE E-2C/HP-41CV FPAS

The calculator code developed for the E-2C was designed primarily using information available in Chapter 11 of the E-2C NATOPS Manual. There are at least two reasons for this.

1. Information available from the manufacturer is generally not available in a convenient format or is closely held as proprietary.
2. The NATOPS Manual is, very simply, supposed to be the final word for aviators needing to know information about their aircraft. Other sources cannot be relied upon unless officially sanctioned. Most of that material is generally not available in a squadron.

The original E-2C program was designed to provide the pilot with max range and max endurance airspeeds to fly for any given set of input parameters read from cockpit instruments during flight. Equations were devised by using regression analysis on specific range charts for the clean and 10 degrees flaps configurations. Corrections applied for altitude, temperature and winds at altitude adjusted the calibrated airspeed to an appropriate indicated airspeed.

Cruise ceiling, the optimal altitude for max range flight, was also computed.

Parameters needed by the program are requested in an interactive manner by the calculator, which is capable of displaying words as well as numbers. Elapsed time from input of the last of five requested input parameters to output of the indicated airspeed to fly is less than 30 seconds. Fuel flow and indicated shaft horsepower to fly the indi ted airspeed are also computed and presented at the end c the program. Additionally, a data algorithm allowed the ot to compute fuel, time and distance to go for a given a t of fuel on board. Climb and descent information is not computed by the program.

The program and report for the E-2C code were submitted to the instructor and NADC at the end of the quarter with a short presentation by each student. Two engineers from NADC listened to each presentation and pressed for additional information. One conclusion reached by virtually all students and conveyed to NADC, however, was that the opportunities for ship based aircraft to use a calculator that computes max range and max endurance parameters is probably limited. An F-14 looks like an E-2 looks like an S-3 in that each aircraft generally flies mission profiles that do not allow use of fuel efficiency codes. Only those short periods of time during transits to or from station, or during holding in marshall, will any of these aircraft need max range or max endurance information. A concern was also expressed regarding the use of a device in a single seat aircraft that requires the pilot to divert attention away from outside the aircraft.[2]

1.2.1 Continuation of the E-2C FPAS

Early in October, 1981, the E-2C FPAS calculator was taken on a flight by an instructor at RVAW-110, the E-2B/E-2C Fleet Replacement Training Squadron for the West Coast at NAS Miramar. The original intent of the flight was to determine if selected output parameters matched the performance of the aircraft. Before such a determination could be made, however, the energy field[3] created by passage of the main beam of the radar over the cockpit rendered the calculator unusable. It was later determined that all program flags were set by the energy field. One of those flags turns the calculator off. Operation was restored after the flight by reseating the batteries. No damage occured to the calculator or memory, and loaded programs remained intact. ROM chips installed in the calculator were not affected, either.

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[2] Additionally, the calculator could not be of any benefit during low level navigation or formation flying because of the external concentration required. Calculators for fighter and attack aircraft will probably gain greatest acceptance as a ready room mission planning aid.

[3] Grumman engineers have assured E-2 flight crew that the microwave energy field that sweeps through the cockpit is not a health hazard. The transitory nature of the beam results in radiation levels less than specified by standards.

During these tests, several aviators in the squadron became interested in the effort and suggested several other ways a calculator could be used. Many of those ideas centered around safety of flight information such as determination of BINGO fuel required data, cross wind landing limitations, and calculation of refusal speed for takeoff.

1.2.2 Directed Studies

During subsequent months, several ideas were generated to cope with informally defined problems with the E-2C FPAS. But no effort could be made without a formal work structure. Professor A.E. Fuhs, who conducted the AE3001 course during the Summer 1981 Quarter, consented to sponsor further work regarding the E-2C program. NADC also provided sponsorship and assistance. Drawing upon several ideas generated between September 1981 and the beginning of the Spring 1982 Quarter, the following research items were agreed upon as a format for a one-time AE4900, Directed Studies in Aeronautical Engineering.

1.2.2.1 E-2C/HP-41CV FPAS Continuation

Work was to be resumed on the E-2C program to redefine program objectives. Primarily, the code was to be simplified by eliminating the 10 degrees of flaps information, adding a descent profile, and possibly eliminating unneeded or unreliable parameters such as fuel flow and horsepower readouts.

1.2.2.2 EMI Effects on the HP-41CV

Electromagnetic interference effects required several simple methods of protecting the HP-41CV from the energy field in cockpit. Possible methods include foil shielding, a metal keyboard mask, and metal-laminated transparent bags.

1.2.2.3 E-2B and C-2A FPAS Programs

Since the flight characteristics of each of the three aircraft are similar, efforts to design standardized programs for each aircraft would be relatively simple. The E-2B program could rely on equations already developed by another student. The C-2A program would have to rely on development of equations patterned after the work on the E-2C.

1.2.2.4 Safety of Flight Programs

The one program most E-2 aviators considered most useful is quick and reliable access to BINGO fuel required. Again, design of a program for the E-2C would provide a guideline for programs for the other two aircraft.

1.2.2.5 Examination of Other Calculators

Since it appeared the HP-41CV might have difficulties coping with the E-2 environment, the possibility of using other types of advanced technology calculators or pocket sized computers was considered. This idea did not work out, however, due to lack of funding.

Chapter II
TECHNICAL DISCUSSION

Prior to discussing the programs, an understanding of the hardware and methodologies is necessary. As mentioned previously, handheld programmable calculators are available that will perform a variety of computations in an interactive manner. Since many types of calculators can be used for any given situation, a full explanation of why the HP-41CV is used for the FPAS program is in order.

A short discussion of regression analysis is also included to familiarize the reader with the methodology used to obtain equations for use in the FPAS programs.

2.1 THE HP-41CV

Handheld programmable calulators go far beyond the realm of "four-bangers", those calculators that perform simple addition, subtraction, multiplication and division. One step beyond that capability includes calculators with at least one memory for temporary, volatile* storage of numbers used in a hand-fed computation sequence.

Programmable calculators include those with more than one memory location, each of which can be accessed by a sequencing operation that "reads" an instruction and performs a desired operation, then moves on to the next instruction. Ob-

* Volatile generally means that any data stored in memory will be lost when power to the calculator is turned off.

viously, these calculators are more complicated to learn to use, but certainly not impossible. Various predefined mathematical operations are also included such as sine, cosine, tangent, log, etc.

Prior to the HP-41, programmable calculators were strictly "number crunchers". The user had to know where the calculator's program was operating in order to interpret a numerical output. Peripheral printers aided the effort, however, by providing a limited interactive, word presentation capability. The TI-59 is probably the best example of this type of calculator. Some TI-59's have been used for FPAS programs, notably one for the AV-8 Harrier. A special mask is used to identify redefined key functions. A special ROM chip, designed especially for the Harrier, makes the program non-volatile.

2.1.1 Basic Features

The HP-41 improves programmable capability considerably. Hewlett-Packard originally issued this calculator as the HP-41C, but later responded to market pressure with the HP-41CV. The two calculators are identical except for the smaller initial memory size of the "C" model. The "CV" has approximately 2.2K of RAM,[5] or 319 registers. Each key

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[5] Random Access Memory (RAM) refers to memory in a computer that is used to perform transitory operations and store instructions and data temporarily. Read Only Memory (ROM) is not accessible to the user. ROM generally contains machine dedicated code for use by the processing unit. ROM may also be used to permanently store program code in non-volatile memory.

represents three or four functions, depending on the mode selected. Variables are stored in registers and are either stored or recalled by program code. The ALPHA mode is used to define alpha-numeric titles or labels that access certain information or spell out interactive wording to which the user responds. The program mode, PRGM on the calculator, allows the user to enter code for later execution. Keys can be assigned program accessing functions so that execution can be initiated easily when in the USER mode.

The calculator's arithmetic operations are conducted in Reverse Polish Notation. RPN eliminates the need for complicated, parenthetically nested equations. Although different from the method of operating a standard calculator, its use can be learned in a few short steps.

Documentation for the calculator is better than average and contains few ambiguities. An interested user can learn enough about the calculator to perform relatively sophisticated programming in about one day. Usage of the FPAS programs requires no special knowledge about the calculator and can be briefed in less than 15 minutes.

Figure 1, reproduced by permission from Hewlett-Packard, shows the calculator keyboard layout and major functions.

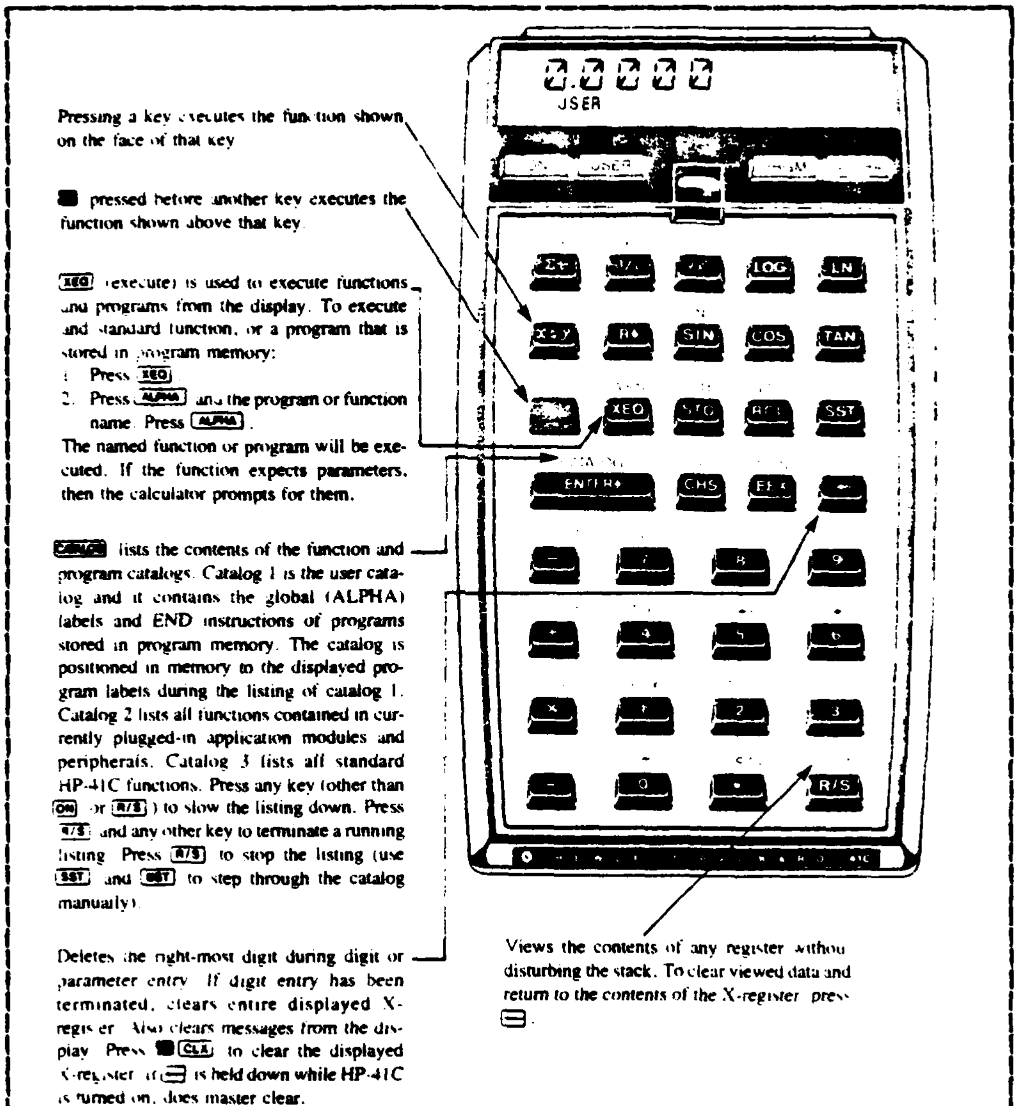

Figure 1: The HP-41CV

Courtesy of Hewlett-Packard Co.

2.1.2 Extended Functions/Memory

Hewlett-Packard recently introduced ROM modules which can be plugged into HP-41CV I/O ports to expand the memory storage capability. The calculator used in this research was supplied with one Extended Functions module and two Extended

Memory modules. The Extended Functions module increases the number of commands that can be accessed directly by the user or by program code. Executable sizing functions can be used to repartition register allocations for different programs.

The Extended Memory modules are used to store program code not currently in use in main memory. Only programs in the main memory of the calculator can be operated. The Extended Memory modules can be considered similar to disk drives on a microcomputer for mass storage of programs and data. The programs are accessed and loaded into main memory when called.

Early on in the design of the FPAS programs at NPS, most program designers realized that the main memory (2.2KB RAM) was not sufficient to handle programs without the use of either two calculators to perform different sections or compromise of the accuracy. For the E-2 and C-2 programs designed for this project, a control program is resident in main memory that calls the desired program from Extended Memory, repartitions the register space as required, and places the program into main memory for operation by the user. When a different program is needed, the current main memory program is erased, and the new one loaded. The Extended Memory modules function essentially like ROM chips; loaded programs remain intact, even when accessed by the main memory program. Fortunately, however, the programs can be modified when required by altering the main memory program and writing over the program stored in Extended Memory.

The Extended Memory programs loaded for each of the three programs written for this project include the FPAS, a BINGO program, and a CROSSWIND LIMITATIONS program. The code for each program has been "tightened" sufficiently to allow the addition of two or three small programs in the future.*

2.2 REGRESSION ANALYSIS

Regression analysis allows researchers to take a given set of data with an apparent functional relationship and devise an equation that will describe that relationship. The equation approximates the data for any given independent variable by determining coefficients for a selected equation form. For instance, one might assume a first order relationship for data of a form such as $y = a + bx$; x is the independent variable and a and b are the coefficients determined by the regression analysis. y is the dependent variable which approximates the desired value. With regression analysis, a set of x and y value pairs are known and the a and b coefficients are determined. Differences between the approximated values of y and the actual value is the residual. Any regression routine will seek to minimize the residual.

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* The Extended Functions module and two Extended Memory modules add about 4KB of memory to the HP-41CV for a total of 6.2KB. The current setup of programs for the E-2C leaves 109 registers available in Extended Memory for future programs.

Regression analysis often requires the consideration of two or more independent variables, a process called multiple linear regression. The equations devised for the E-2/C-2 FPAS programs required use of multiple variables. For instance, the calibrated airspeed to define no-wind, max range values is a function of aircraft gross weight (GW) and pressure altitude (PA). The Minitab program, resident on the IBM370/3033 at the Naval Postgraduate School, was used to formulate appropriate equations.

Simpler relationships involving one variable or easily recoginized functional relationship patterns were regressed using a curve fitting program on the HP-41CV.

Chapter III
THE E-2C/HP-41CV PROGRAMS

Since the E-2C program was used as the control program to devise codes for the other two aircraft, a more complete description of these codes will be presented here. Flowcharts and a listing of program code are presented after each description rather than in separate appendices to avoid confusion.

3.1 THE E-2C FPAS PROGRAM

The E-2C Flight Performace Advisory Program is called by the main memory accessing program from Extended Memory and loaded into main memory in about 30 seconds. The flow chart should be referenced to understand the theory of operation.

3.1.1 Program Initiation

Program operation is initiated by pressing the START key at the upper left corner of the keyboard.[7] The program will display "**E-2C FPAS**" for about one second, then proceed to request needed information with the following displays:

1. "BASIC WT = ?", then
2. "CARGO WT = ?", then
3. "NO. CREW = ?".

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[7] Subsequently, keys will be referred to by a coded position based on a row/column numbering system. The START key is on row 1, column 1; hence, key 11. There are 8 rows with 5 columns in the first three rows, and 4 columns each in lower rows.

Each label will stop program operation until the user responds by keying in the appropriate number. Program operation proceeds to the next label when Run/Stop (R/S: key 84) is pressed after each numerical entry.

Finally, "PROFILE?" is displayed, asking the user to select one of three modes of operation: RANGE, ENDURANCE, or DESCENT.

3.1.2 RANGE

Pressing the RANGE key (12) initiates the calculation of maximum range indicated airspeed to fly corrected for altitude, temperature and winds at altitude. Upon pressing the key, "**MAX RANGE*" displays as an echo check verification of the selection, followed by:

1. "ALT = FT?", enter current altitude from the altimeter;
2. "OAT = C", outside air temperature in degrees centigrade (the CHS (change sign) key (42) places a negative sign in front of a number);
3. "IAS = KTS?", current indicated airspeed in knots (this number is used to correct OAT for heating effects on the temperature probe);
4. "FUEL = LBS?", total fuel weight read from the quantity gages.

Each of these parameters are loaded into appropriate registers for later access by the program. Temperature deviation (TDEV), a function of OAT and altitude (PA), is then calculated for use in a Cruise Ceiling (CC) calculation, a function of TDEV and Gross Weight (GW). Max Range Calibrated

Airspeed (MRCAS), from the NATOPS charts, is then computed as a function of PA and GW.

The inverse of SQRT sigma (SSI) is calculated and stored for use in later true airspeed (TAS) computations. A compressibility correction based on PA and CAS is also computed.

Winds are accounted for by asking the user if the ground speed is available (from CAINS or TACAN calculations). Response is with the YES or NO keys, (15) or (25). The label will read "GS,AVAIL? Y/N". If yes, the program will ask "GS = KTS?"; enter the value and press R/S. If no, the program will respond, "INPUT WINDS.."; the dots indicate a temporary label with a query to follow.

1. "WIND DIR = ?", enter forecast or computed winds in degrees, 001 to 360;
2. "WIND VEL = ?", enter forecast or computed winds in knots;
3. "A/C HDG = ?", enter aircraft heading in degrees, 001 to 360.

Headwind calculations are a function of TAS based indicated airspeed (TASi). After determining if the headwind is positive or negative (tailwind), corrections are applied to the CAS to adjust for winds. This value is then corrected for compressibility and stored for later display. The calculator then displays, "*DATA READY*".

3.1.3 ENDURANCE

The ENDURANCE profile functions much the same way as the RANGE profile. Subroutine AIOFG again asks for altitude, airspeed, OAT, and fuel weight, then calculates gross weight. Max endurance is easily calculated as a function of gross weight only. Headwind corrections, obviously, are not performed.

Equivalent (indicated)* airspeed and true airspeed are then calculated and stored for later display.

3.1.4 DESCENT

The DESCENT profile calculates an indicated airspeed to fly a max range descent such as might be used during a BINGO to a shore based field. Headwind corrections have been incorporated into this algorithm; the assumption is made, however, that the RANGE profile has been run at least once prior to DESCENT so that an approximate headwind correction can be applied.

When selected, the DESCENT profile initially asks for present altitude, then fuel wieght, then the desired level off altitude. Gross weight is calculated and stored.

Since the charts in the NATOPS manual show a weight only dependency above 10000 feet and a weight and altitude dependency below 10000 feet, the program determines whether present altitude is above or below 10000 and uses the correct

* Position error corrections for each of the three aircraft are negligible and not computed. Hence, EAS is approximately equal to IAS.

set of equations to determine the CAS. Headwind corrections are then applied, and indicated airspeed is calculated. Descent distance, the distance from the field to start the descent, is calculated as a function of present altitude and level-off altitude.

Stored values are then displayed in a short routine that also warns the user to increase IAS 1 knot per 1000 feet below 10000 feet. A label also warns the pilot to use 500 SHP for the descent. Readers will note that the NATOPS manual specifies flight idle. The 500 SHP value was chosen because of the common knowledge ability to simulate feathered flight by using 500 SHP.[9]

3.1.5 DATA

The DATA algorithm can be called at any time to display the values calculated for the latest run of the RANGE or ENDURANCE profiles. The DESCENT profile displays its own values separately.

If the RANGE profile was the most recently run selection, the DATA algorithm will display a recommended IAS to fly max range,[10] followed by several other parameters of interest.

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[9] The exact value of SHP to use can be determined in flight in the following manner. At a given altitude with one engine feathered, trim the aircraft for straight and level flight at the IAS specified for max range descent at that weight and altitude. Without retrimming, restart the feathered engine and adjust its power setting to that required to duplicate the flight conditions previously set for feathered flight. Note the SHP on the restarted engine and use this value. Several aircraft should be tested in this manner to arrive at a nominal value.

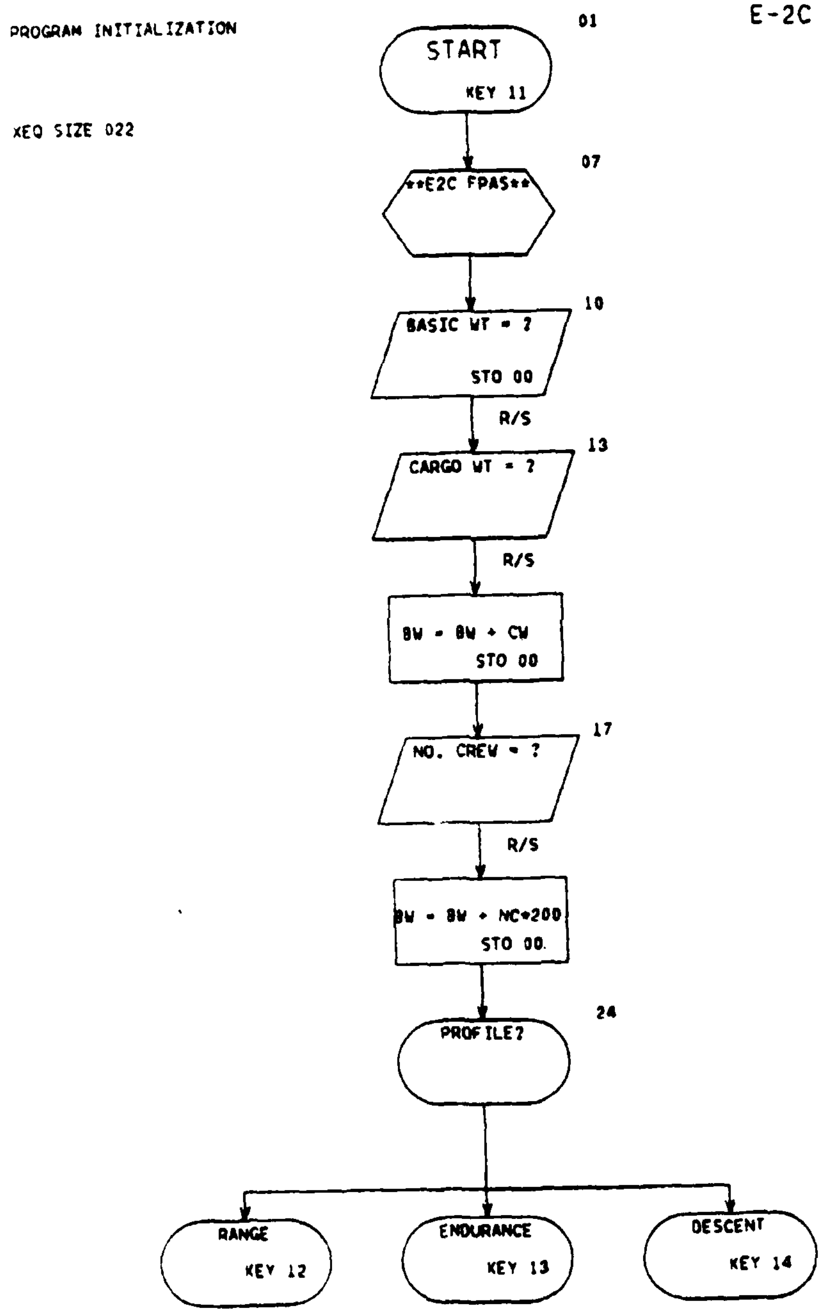
[10] There exists an AOA to fly max range at any weight (no wind conditions). Informal tests indicate this AOA to be about 16 units.

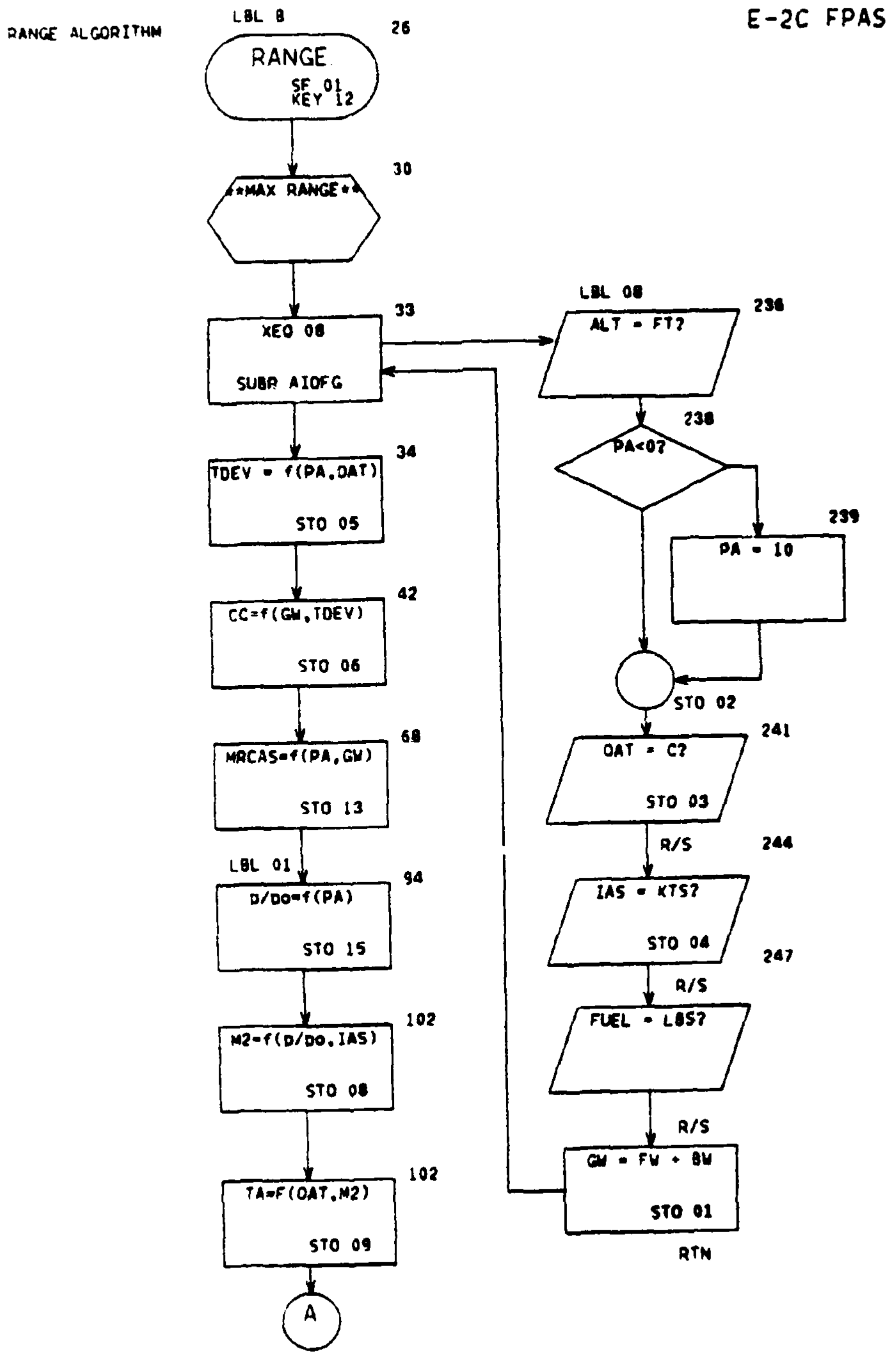
Each value may be observed by pressing R/S to proceed to the next. After all values have been seen, the program will cycle back to the MRIAS value again.

3.1.6 E-2C FPAS Flowcharts

The following nine pages present the E-2C FPAS algorithm in flowchart format for a conceptual understanding of program operation. Numbers adjacent to function blocks refer to line numbers in the FPAS code that follows.

E-2C FPAS


PROGRAM INITIALIZATION
XEQ SIZE 022
01
START
KEY 11
07
E2C FPAS
10
BASIC WT = ?
STO 00
R/S
13
CARGO WT = ?
R/S
BW = BW + CW
STO 00
17
NO. CREW = ?
R/S
BW = BW + NC*200
STO 00
24
PROFILE?
RANGE
KEY 12
ENDURANCE
KEY 13
DESCENT
KEY 14

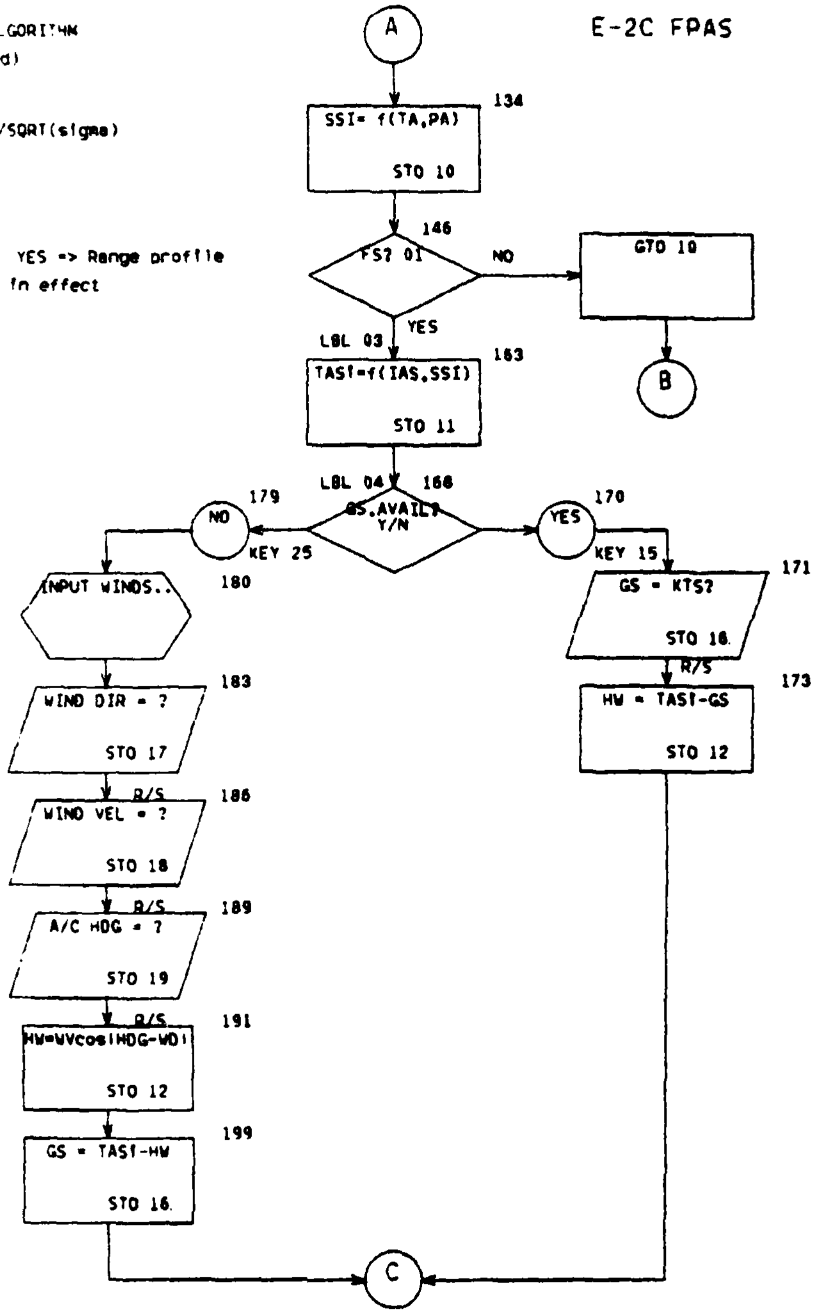

RANGE ALGORITHM
E-2C FPAS
LBL B
26
RANGE
SF 01
KEY 12
30
MAX RANGE
33
XEQ 08
SUBR AIOFG
34
TDEV = f(PA,OAT)
STO 05
42
CC=f(GW,TDEV)
STO 06
68
MRCAS=f(PA,GW)
STO 13
LBL 01
94
D/DO=f(PA)
STO 15
102
M2=f(D/DO,IAS)
STO 08
102
TA=F(OAT,M2)
STO 09
A
LBL 08
236
ALT = FT?
238
PA<0?
239
PA = 10
STO 02
241
OAT = C?
STO 03
R/S
244
IAS = KTS?
STO 04
247
R/S
FUEL = LBS?
R/S
GW = FW + BW
STO 01
RTN

RANGE ALGORITHM
(cont'd)

E-2C FPAS

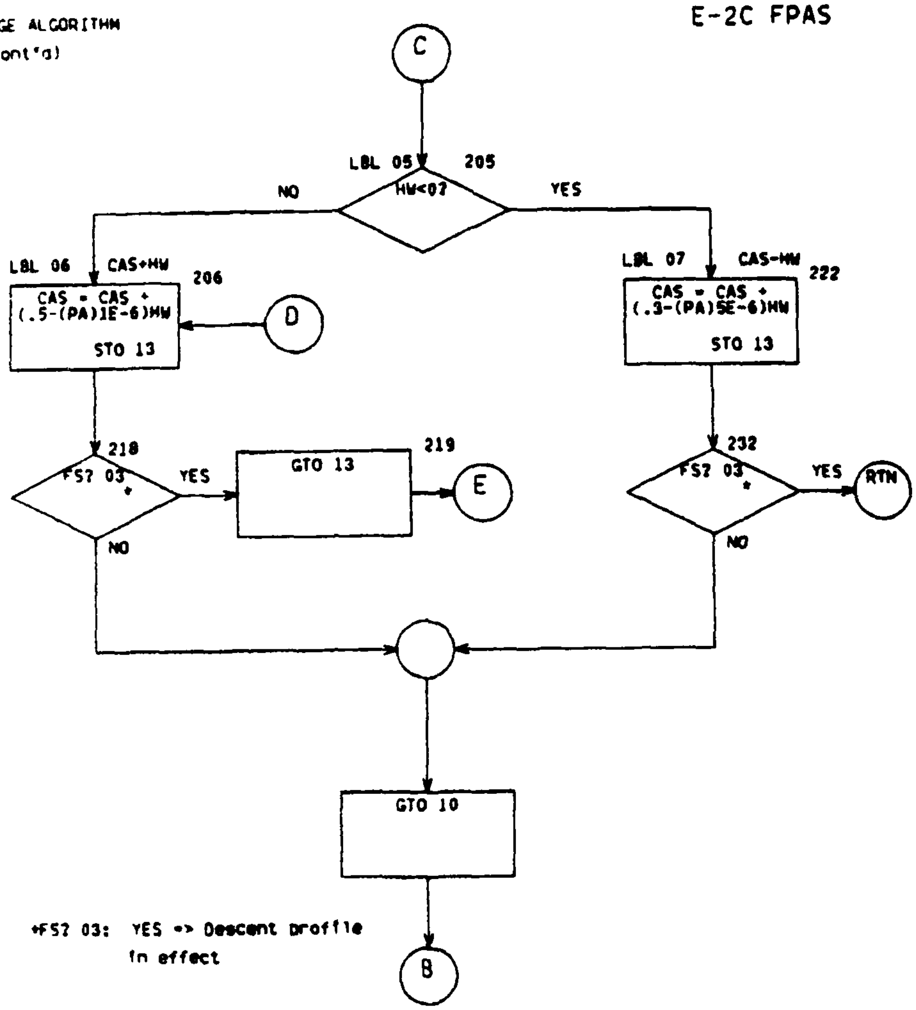
SSI = 1/SQRT(sigma)

FS? 01: YES => Range profile in effect

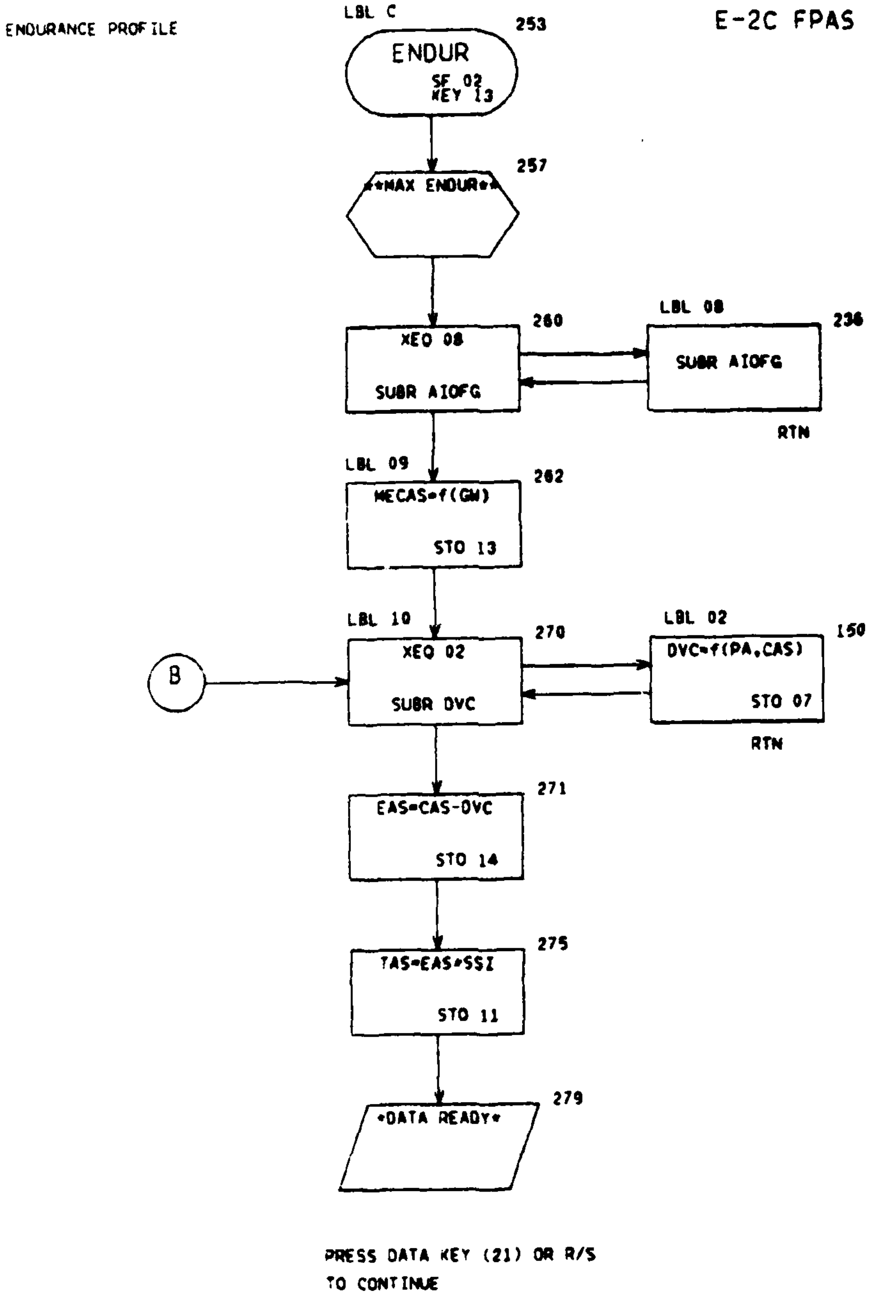


RANGE ALGORITHM
(cont'd)

E-2C FPAS

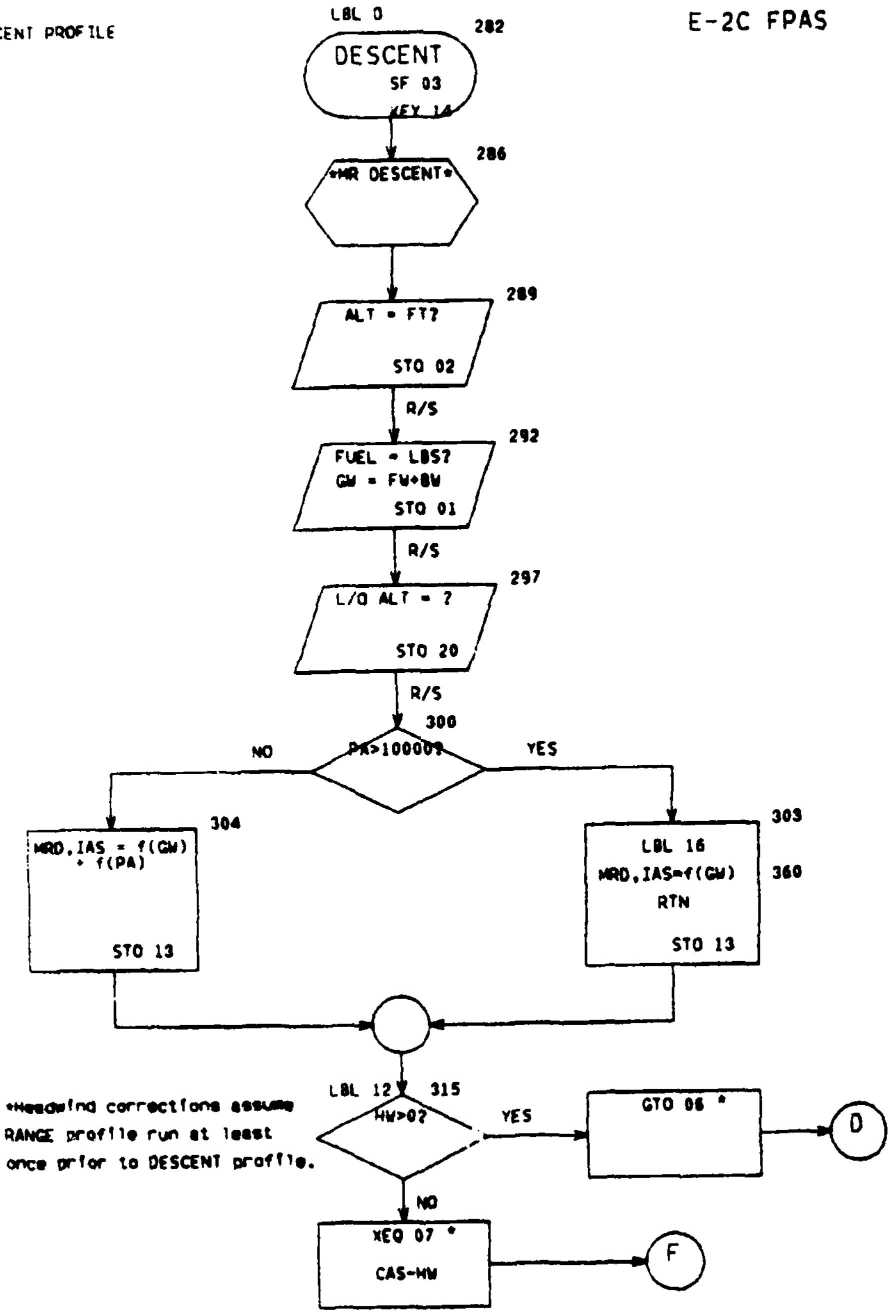


*FS? 03: YES => Descent profile in effect


ENDURANCE PROFILE
E-2C FPAS
LBL C
253
ENDUR
SF 02
KEY 13
257
MAX ENDUR
260
XEQ 08
SUBR AIOFG
LBL 08
236
SUBR AIOFG
RTN
LBL 09
262
MECAS=f(GW)
STO 13
LBL 10
270
XEQ 02
SUBR DVC
B
LBL 02
150
DVC=f(PA,CAS)
STO 07
RTN
271
EAS=CAS-DVC
STO 14
275
TAS=EAS*SSI
STO 11
279
DATA READY
PRESS DATA KEY (21) OR R/S
TO CONTINUE

DESCENT PROFILE

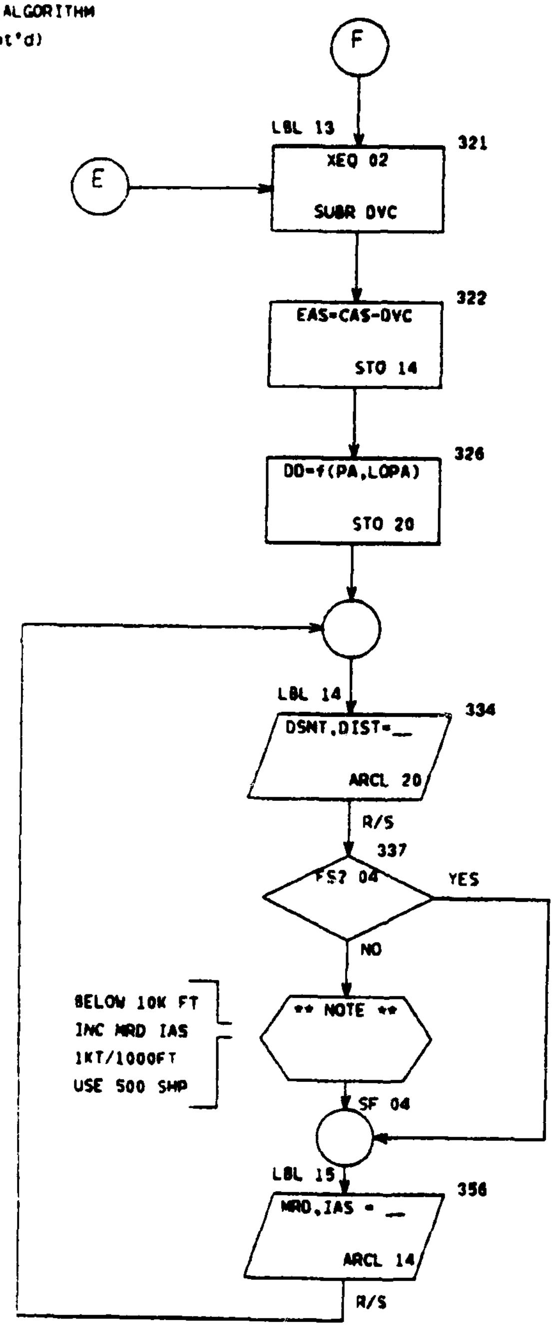
E-2C FPAS



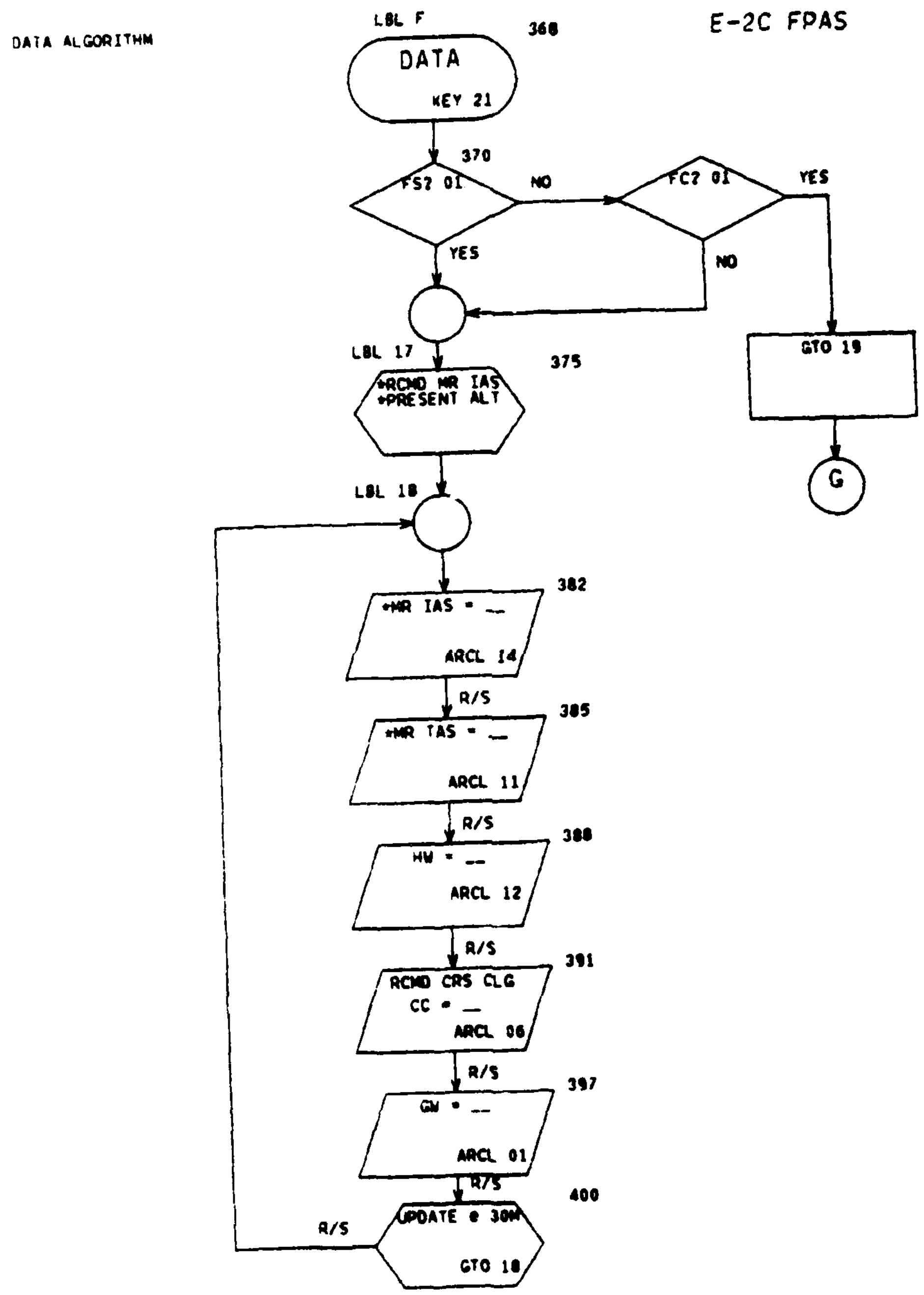
*Headwind corrections assume RANGE profile run at least once prior to DESCENT profile.

DESCENT ALGORITHM
(cont'd)

E-2C FPAS



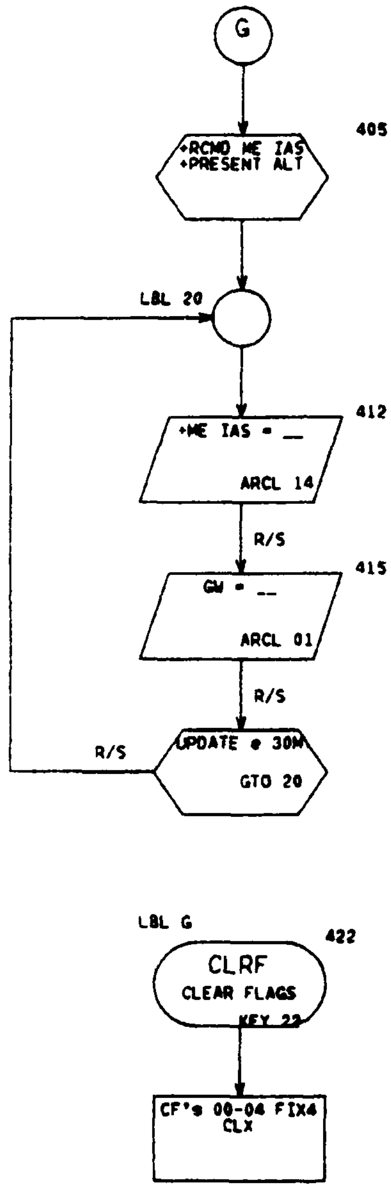
7/9


DATA ALGORITHM
E-2C FPAS
LBL F
368
DATA
KEY 21
370
FS? 01
NO
FC? 01
YES
YES
NO
GTO 19
G
LBL 17
375
*RCMD MR IAS
*PRESENT ALT
LBL 18
382
*MR IAS = __
ARCL 14
R/S
385
*MR TAS = __
ARCL 11
R/S
388
HW = __
ARCL 12
R/S
391
RCMD CRS CLG
CC = __
ARCL 06
R/S
397
GW = __
ARCL 01
R/S
400
UPDATE @ 30M
GTO 18
R/S

8/9

DATA ALGORITHM
(cont'd)

E-2C FPAS



E-2C FPAS/HP-41CV Code (June 1982; 1/3)

```
01♦LBL "STF"
02 CF 01
03 CF 02
04 CF 03
05 CF 04
06 CLRG
07 "**E2C FPAS**"
08 AVIEW
09 PSE
10 "BASIC WT = ?"
11 PROMPT
12 STO 00
13 "CARGO WT = ?"
14 PROMPT
15 +
16 STO 00
17 "NO. CREW = ?"
18 PROMPT
19 200
20 *
21 RCL 00
22 +
23 STO 00
24 "PROFILE?"
25 PROMPT
26♦LBL B
27 SF 01
28 CF 02
29 CF 03
30 "**MAX RANGE*"
31 AVIEW
32 PSE
33 XEQ 00
34 RCL 03
35 15
36 -
37 RCL 02
38 198 E-5
39 *
40 +
41 STO 05
42 30
43 RCL 05
44
45 -.0031
46 *
47 1
48 +
49 .705
50 RCL 01
51 *
52 *
53 CHS
54 30
55 RCL 05
56 -
57 78.67
58 *
59 +
60 58480
61 +
62 100
63 /
64 INT
65 100
66 *
67 STO 06
68 179.67
69 RCL 02
70 173 E-5
71 *
72 -
73 RCL 01
74 816 E-6
75 *
76 +
77 RCL 01
78 X↑2
79 RCL 02
80 X↑2
81 516 E-20
82 *
83 *
84 +
85 RCL 02
86 1 E-3
87 *
88 LN
89 3.074
90 *
91 -
92 STO 13
93♦LBL 01
94 RCL 02
95 -6875 E-9
96 *
97 1
98 +
99 5.2563
100 Y↑X
101 STO 15
102 RCL 04
103 661.7
104 /
105 X↑2
106 .2
107 *
108 1
109 +
110 3.5
111 Y↑X
112 1
113 -
114 RCL 15
115 1/X
116 *
117 1
118 +
119 .286
120 Y↑X
121 1
122 -
123 5
124 *
125 STO 08
126 .2
127 *
128 1
129 +
130 1/X
131 RCL 03
132 *
133 STO 09
134 1936 E-6
135 *
136 RCL 02
137 1500
138 -
139 2112 E-8
140 *
141 +
142 E↑X
143 .982
144 *
145 STO 10
146 FS? 01
147 GTO 03
148 GTO 10
149♦LBL 02
150 RCL 02
```

E-2C/FPAS HP-41CV Code (June 1982; 2/3)

```
91 E-6
*
E↑X
1 E-7
*
RCL 13
2.852
Y↑X
*
STO 07
RTN
◆LBL 03
RCL 04
RCL 10
*
STO 11
◆LBL 04
"GS,AVAIL? Y/N"
PROMPT
◆LBL E
"GS = KTS?"
PROMPT
STO 16
RCL 11
RCL 16
-
STO 12
GTO 05
◆LBL J
"INPUT WINDS.."
AVIEW
PSE
"WIND DIR = ?"
PROMPT
STO 17
"WIND VEL = ?"
PROMPT
STO 18
"A/C HDG = ?"
PROMPT
STO 19
RCL 17
-
ABS
COS
RCL 18
*
STO 12
RCL 11
RCL 12
-
STO 16
RCL 12
◆LBL 05
X<0?
GTO 07
◆LBL 06
.5
RCL 02
1 E-5
*
-
RCL 12
*
RCL 13
+
STO 13
FS? 03
GTO 13
GTO 10
◆LBL 07
.3
RCL 02
5 E-6
*
-
RCL 12
*
RCL 13
+
STO 13
FS? 03
RTN
GTO 10
◆LBL 08
"ALT = FT?"
PROMPT
X<0?
10
STO 02
"OAT = C?"
PROMPT
STO 03
"IAS = KTS?"
PROMPT
STO 04
"FUEL = LBS?"
PROMPT
RCL 00
+
STO 01
RTN
◆LBL C
SF 02
CF 01
CF 03
"**MAX ENDUR*"
AVIEW
PSE
XEQ 08
◆LBL 09
65
RCL 01
125 E-5
*
+
STO 13
GTO 01
◆LBL 10
XEQ 02
RCL 13
RCL 07
-
STO 14
RCL 10
*
STO 11
BEEP
"*DATA READY*"
PROMPT
GTO F
◆LBL D
SF 03
CF 01
CF 02
"*MR DESCENT*"
AVIEW
PSE
"ALT = FT?"
PROMPT
STO 02
"FUEL = LBS?"
PROMPT
RCL 00
+
STO 01
"L/O ALT = ?"
PROMPT
STO 20
10000
```

E-2C/FPAS HP-41CV Code (June 1982; 3/3)

```
RCL 02
X>Y?
GTO 11
XEQ 16
RCL 02
.001
*
-
10
+
GTO 12
◆LBL 11
XEQ 16
◆LBL 12
STO 13
RCL 12
X>0?
GTO 06
XEQ 07
◆LBL 13
XEQ 02
RCL 13
RCL 07
-
STO 14
.00233
RCL 02
RCL 20
-
*
STO 20
◆LBL 14
FIX 0
"DSNT.DIST="
ARCL 20
PROMPT
FS? 04
GTO 15
" ** NOTE **"
AVIEW
PSE
"BELOW 10K FT"
AVIEW
PSE
"INC MRD IAS"
AVIEW
PSE
"1 KT/1000FT"
AVIEW
PSE
SF 04
"USE 500 SHP"
AVIEW
PSE
◆LBL 15
"MRD IAS="
ARCL 14
PROMPT
GTO 14
◆LBL 16
RCL 01
32687 E-10
*
E↑X
130.4677
*
RTN
◆LBL F
FIX 0
FS? 01
GTO 17
FC? 01
GTO 19
◆LBL 17
"*RCMD MR IAS"
AVIEW
PSE
"*PRESENT ALT"
AVIEW
PSE
◆LBL 18
"*MR IAS="
ARCL 14
PROMPT
"*MR TAS="
ARCL 11
PROMPT
"*HW = "
ARCL 12
PROMPT
"RCMD CRS CLG"
AVIEW
PSE
"CC = "
ARCL 06
PROMPT
"GW = "
ARCL 01
PROMPT
"UPDATE e 30M"
AVIEW
PSE
GTO 18
◆LBL 19
"+RCMD ME IAS"
AVIEW
PSE
"+PRESENT ALT"
AVIEW
PSE
◆LBL 20
"+ME IAS="
ARCL 14
PROMPT
"GW = "
ARCL 01
PROMPT
"UPDATE e 30M"
AVIEW
PSE
GTO 20
◆LBL G
CF 00
CF 01
CF 02
CF 03
CF 04
FIX 4
CLX
.END.
```

3.1.8 Variable Locations and Governing Equations

3.1.8.1 Variable Register Locations

The following variables are applicable to all three FPAS programs.

BW - R00 (Basic Weight)
GW - R01 (Gross Weight)
PA - R02 (Pressure Altitude)
OAT - R03 (Outside Air Temp)
IAS - R04 (Indicated Airspeed)
TDEV - R05 (Temp Deviation)
CC - R06 (Cruise Ceiling)
DVC - R07 (Delta Vc; Compressibility Correction)
M2 - R08 (Mach Number Squared)
TA - R09 (Ambient Temperature)
SSI - R10 (SQRT Sigma Inverse)
TAS - R11 (True Airspeed)
HW - R12 (Headwind)
CAS - R13 (Calibrated Airspeed)
EAS - R14 (Equivalent Airspeed)
GS - R16 (Groundspeed)
WD - R17 (Wind Direction)
WV - R18 (Wind Velocity)
HDG - R19 (Aircraft Heading)
LOPA - R20 (Level off altitude)

3.1.8.2 Governing Equations

Single asterisks "*" imply multiplication, double "**" imply exponent.

Temperature Deviation: TDEV = f(OAT,PA)

TDEV = OAT - 15 + (198E-5)(PA)

Cruise Ceiling: CC = f(TDEV,GW)

CC = 58480 + 78.67(30-TDEV) -

- (1-0.0031(30-TDEV))(0.705)(GW)

Max Range Calibrated Airspeed: MRCAS = f(PA,GW)

MRCAS = 179.67 - (173E-5)(PA) + (816E-6)(GW)

+ (516E-20)(PA)**2(GW)**2 -

- 3.074LN(PA E-3)

Max Endurance Calibrated Airspeed: MECAS = f(GW)

MECAS = 65 + (125E-5)(GW)

Delta, Atmospheric Pressure Ratio: p/po = f(PA)

p/po = (1-(6875E-9)(PA))**5.2563

Mach Number Squared: M2 = f(p/po,IAS)

M2 = 5((po/p((1+.2(IAS/661.7)**2)**3.5-1)+1)**.286-1)

Ambient Temperature: TA = f(OAT,M2)

TA = OAT/(1-.2*M2)

SQRT Sigma Inverse: SSI = f(TA,PA)

SSI = .982exp((1936E-6)(TA) + (2112E-8)(PA-1500))

Delta Vc (Comp Corr): DVC = f(PA,CAS)

DVC = ((1E-7)exp(91E-6)(PA))CAS**2.852)

IAS Dependent TAS: TASi

TASi = IAS * SSI

Headwind: HW

HW = TASi - GS

CAS Corrected for Headwind: CAS+HW

CAS+HW = CAS + (.5-(PA)E-5)(HW)

CAS Corrected for Tailwind: CAS-HW

$$\text{CAS-HW} = \text{CAS} + (.3-(\text{PA})5\text{E}{-6})(\text{HW})$$

Equivalent Airspeed: EAS

$$\text{EAS} = \text{CAS} - \text{DVC}$$

True Airspeed: TAS

$$\text{TAS} = \text{EAS} * \text{SSI}$$

Max Range Descent CAS (>10000): MRDCAS = f(GW)

$$\text{MRDCAS} = 130.4677\exp((\text{GW})(32687\text{E}{-10}))$$

Max Range Descent CAS (<10000): MRDCAS = f(GW)+f(PA)

$$\text{MRDCAS} = 130.4677\exp((\text{GW})(32687\text{E}{-10})) + 10 - .001(\text{PA})$$

3.2 THE E-2C BINGO PROGRAM

First efforts to design a BINGO program for the E-2C included use of regression analysis to approximate the values listed in the BINGO charts. This effort was abandoned early on as being impractical and inaccurate. The charts are already rounded off the nearest five pound increment and the exact method used to compute the original values is unknown.

The method used in this report is to load all the values of fuel required and time required into a data set, then use a calculator program to access the correct value. There are seven configurations; only the boldface fuel required values are used. All other values are disregarded. Sorting algorithms are used to determine the correct recommended altitude to fly and similar methods are used to calculate the appropriate address for indirect addressing of the correct fuel-required:time-required value.

Interpolation calculates fuel and time required for values not explicitly shown in the charts. No corrections are made for headwinds or tailwinds. Since fuel required and time required are stored in the data set as a decimal number, integer functions and appropriate calculations are used to separate the indirectly accessed value for storage and display.

3.2.1 Theory of Operation

The BINGO program can be easily selected by the user by pressing the shift key, then key 21. The program loads and is ready for use in about 30 seconds. Once loaded, START is pressed. An echo check is displayed, "**E2C BINGO*", followed by a request for "DIST TO GO?". Then, "SELECT.., ENGS, GR, FLPS".

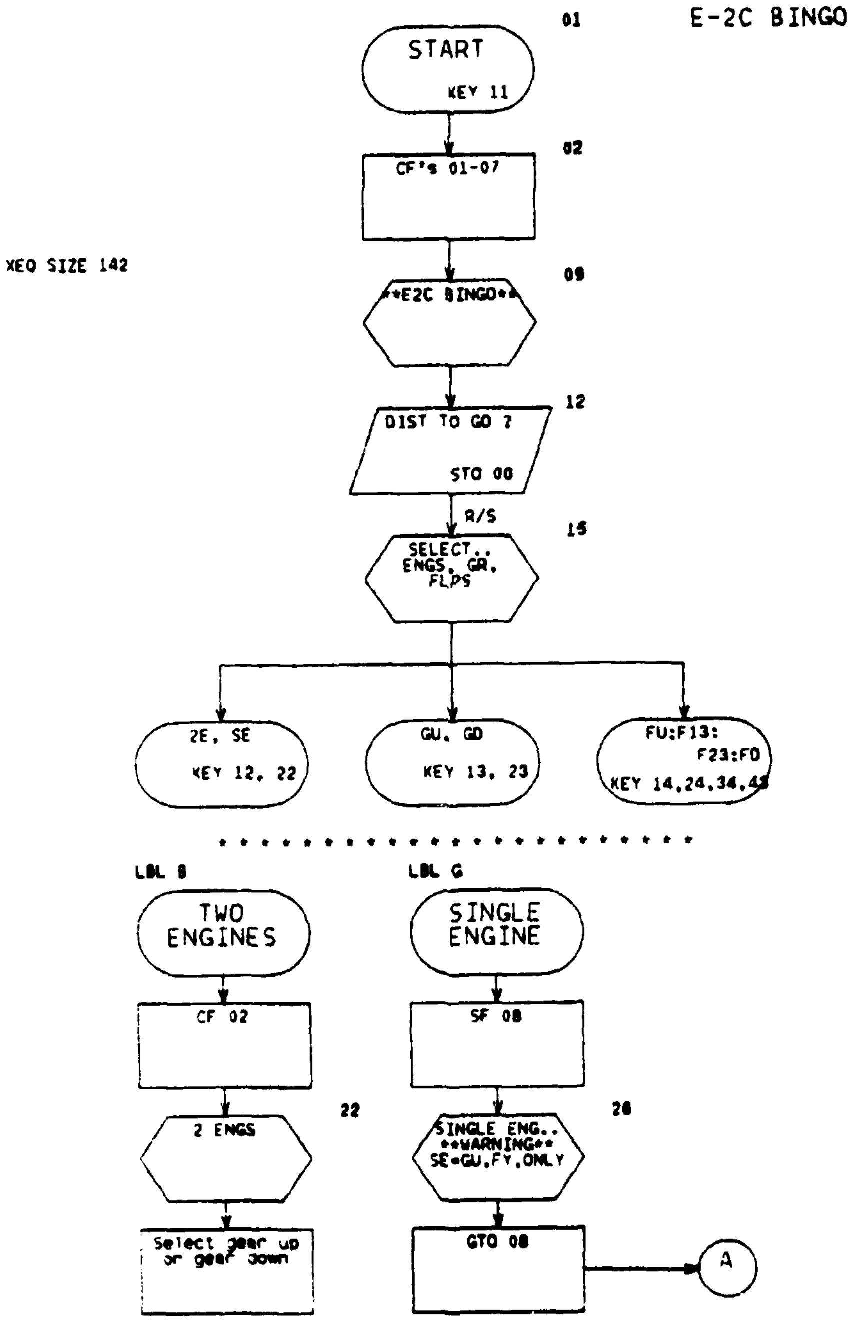
At this point, the pilot determines the probable configuration for any BINGO situation that might arise. Generally, two engines, gear up and flaps up can be assumed. If, however, the aircraft was experiencing a stuck flaps or gear down situation, those configurations could also be selected. Time permitting, fuel and time required for all seven configurations could be requested and written down in a short amount of time.

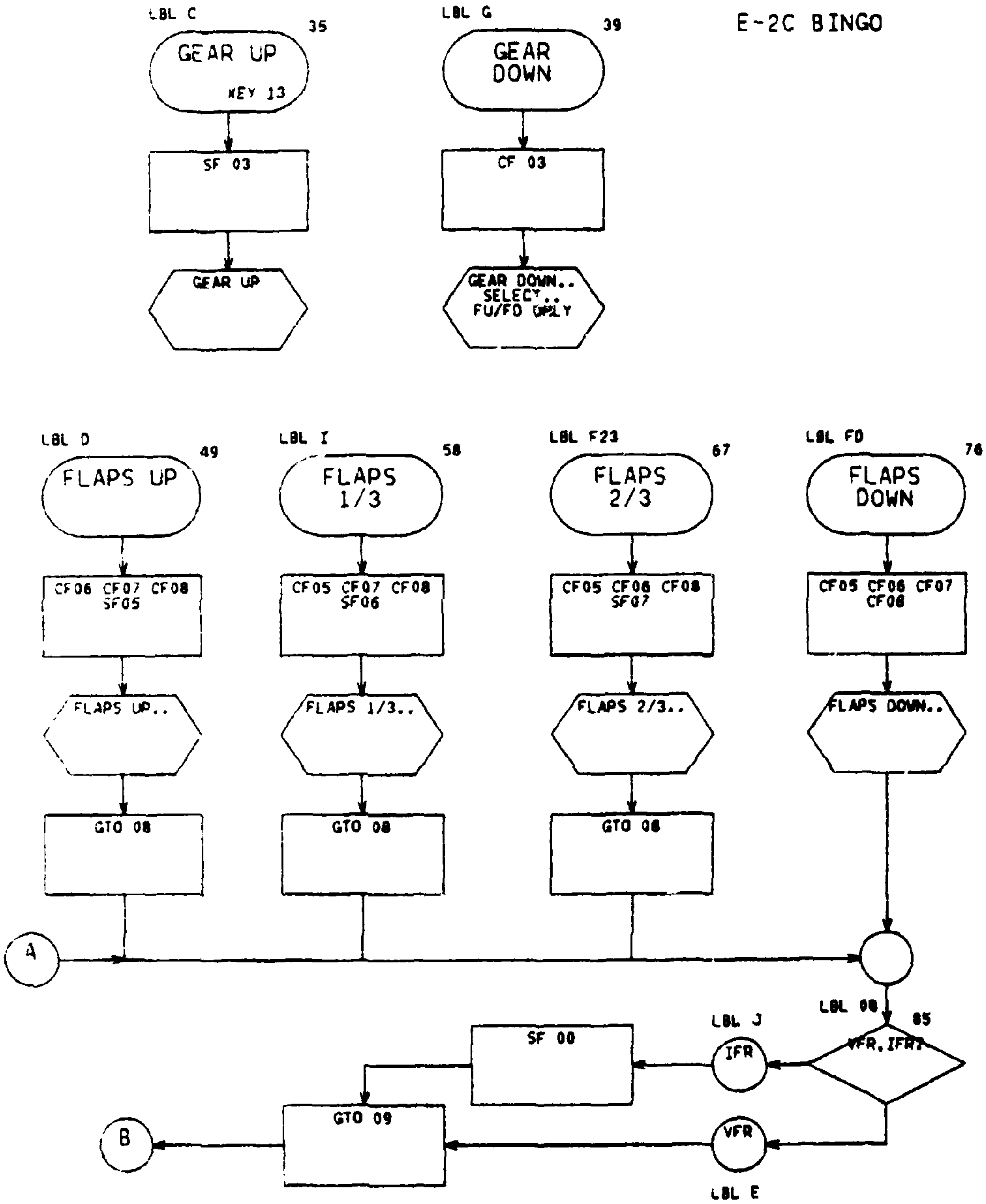
The 2E key is now pressed, followed by GU, then FU. Program operation will proceed to display "VFR, IFR?" so that 1000 pounds can be added to the fuel required if IFR is selected. After the VFR or IFR key is pressed, program operation proceeds automatically without user assistance. The correct value of fuel and time required are selected by the program and stored for display. Flowchart operation is pictured in the following pages. Fuel required, time required, recommended altitude to fly, initial sea level IAS to fly, a climb schedule airspeed correction, and initial power setting are all displayed to the user.

3.2.2 Future Corrections

The current program configuration performs exactly what the pilot would find if the pocket checklist was used. The advantage to using the calculator is the ability to chose new configurations without sorting through several pages of configurations scattered in the checklist booklet. The checklist booklet has always been somewhat difficult to use; hopefully, the calculator will ease that problem somewhat.

The next modification to this program, a subject of future research, will be to incorporate headwind and tailwind corrections to fuel and time required values.

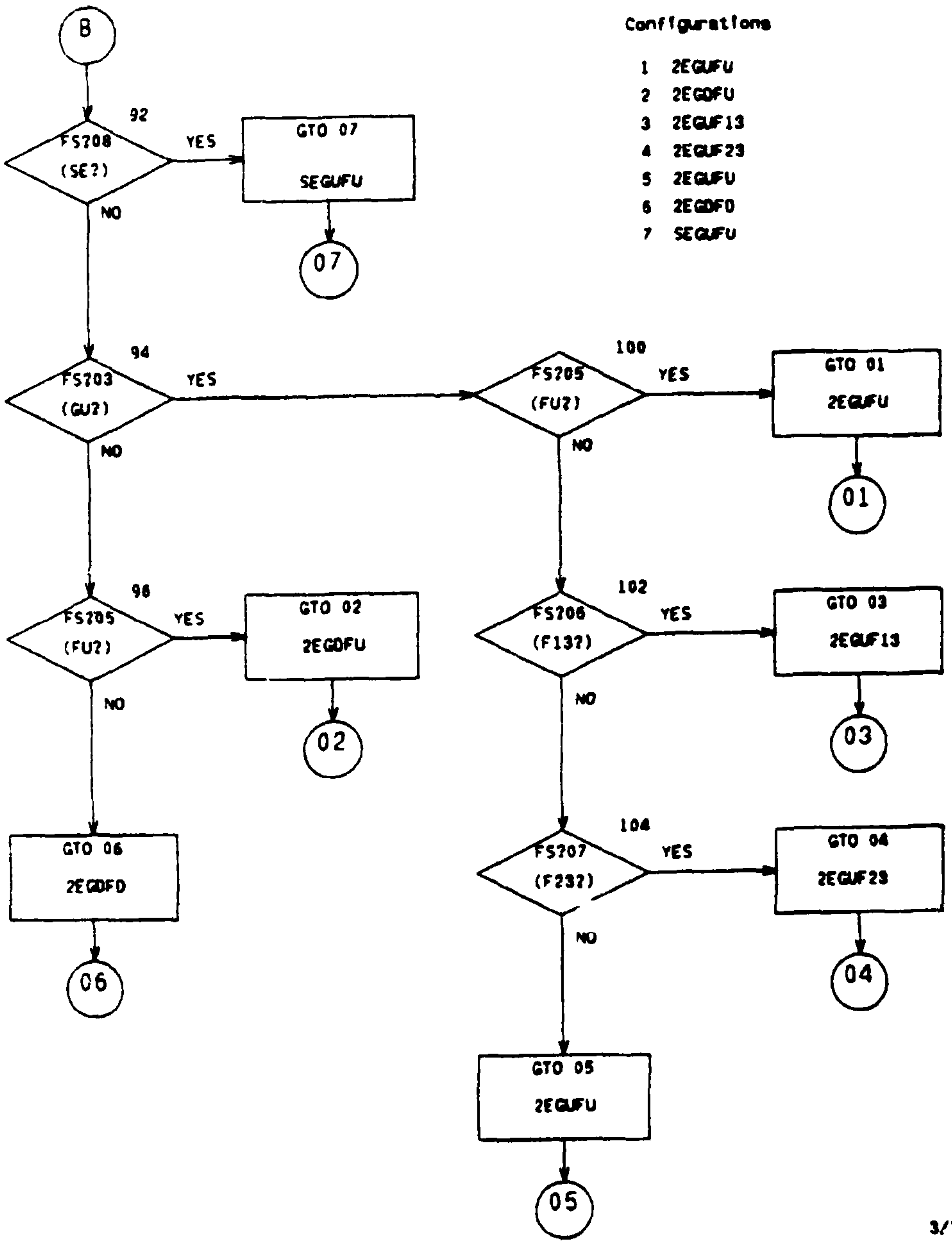

E-2C BINGO
01
START
KEY 11
02
CF's 01-07
XEQ SIZE 142
09
E2C BINGO
12
DIST TO GO ?
STO 00
R/S
15
SELECT..
ENGS, GR,
FLPS
2E, SE
KEY 12, 22
GU, GD
KEY 13, 23
FU:F13:
F23:FD
KEY 14,24,34,44
LBL B
TWO
ENGINES
LBL G
SINGLE
ENGINE
CF 02
SF 08
22
2 ENGS
28
SINGLE ENG..
WARNING
SE=GU,FY,ONLY
Select gear up
or gear down
GTO 08
A


E-2C BINGO
LBL C
35
GEAR UP
KEY 13
SF 03
GEAR UP
LBL G
39
GEAR DOWN
CF 03
GEAR DOWN..
SELECT..
FU/FD ONLY
LBL D
49
FLAPS UP
CF06 CF07 CF08
SF05
FLAPS UP..
GTO 08
LBL I
58
FLAPS 1/3
CF05 CF07 CF08
SF06
FLAPS 1/3..
GTO 08
LBL F23
67
FLAPS 2/3
CF05 CF06 CF08
SF07
FLAPS 2/3..
GTO 08
LBL FD
76
FLAPS DOWN
CF05 CF06 CF07
CF08
FLAPS DOWN..
A
LBL 08
85
VFR,IFR?
LBL J
IFR
SF 00
GTO 09
B
VFR
LBL E

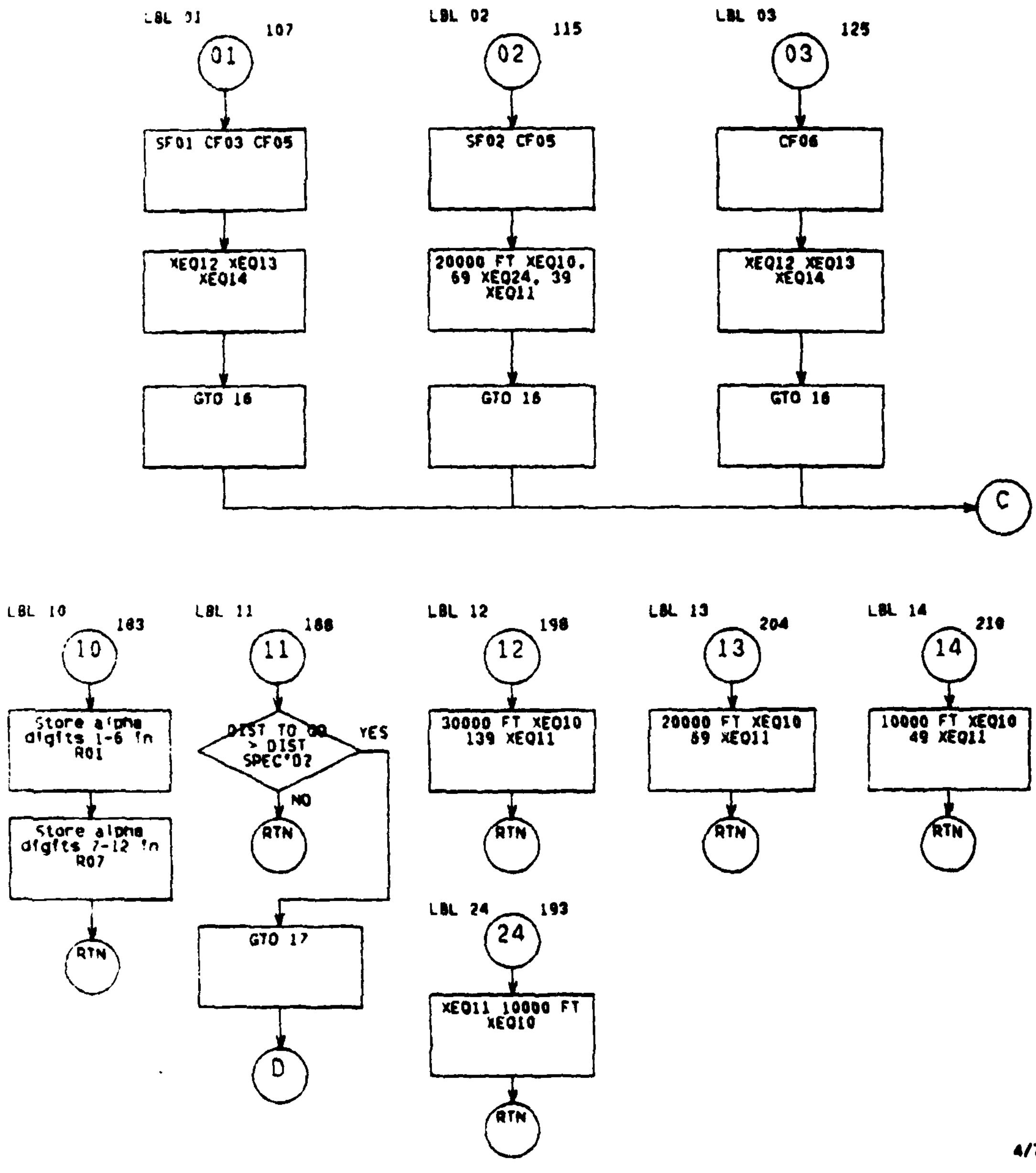
E-2C BINGO

Configurations

1 2EGUFU
2 2EGDFU
3 2EGUF13
4 2EGUF23
5 2EGUFU
6 2EGDFD
7 SEGUFU



E-2C BINGO


LBL 01
107
01
SF01 CF03 CF05
XEQ12 XEQ13 XEQ14
GTO 16
LBL 02
115
02
SF02 CF05
20000 FT XEQ10, 69 XEQ24, 39 XEQ11
GTO 16
LBL 03
125
03
CF06
XEQ12 XEQ13 XEQ14
GTO 16
C
LBL 10
183
10
Store alpha digits 1-6 in R01
Store alpha digits 7-12 in R07
RTN
LBL 11
188
11
DIST TO GO > DIST SPEC'D?
YES
NO
RTN
GTO 17
D
LBL 12
198
12
30000 FT XEQ10 139 XEQ11
RTN
LBL 13
204
13
20000 FT XEQ10 69 XEQ11
RTN
LBL 14
210
14
10000 FT XEQ10 49 XEQ11
RTN
LBL 24
193
24
XEQ11 10000 FT XEQ10
RTN

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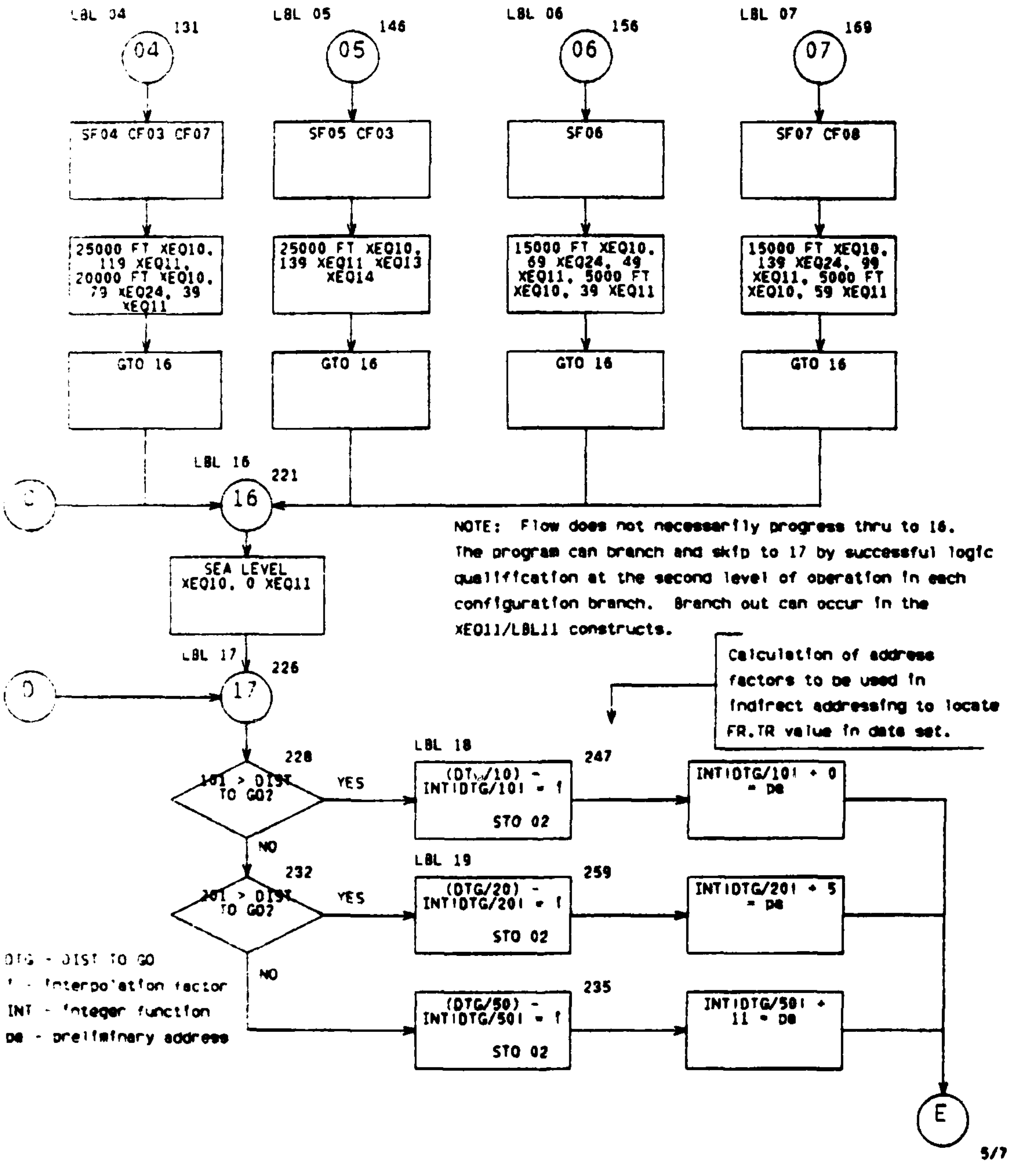
E-2C BINGO


LBL 04
131
04
SF04 CF03 CF07
25000 FT XEQ10, 119 XEQ11, 20000 FT XEQ10, 79 XEQ24, 39 XEQ11
GTO 16
LBL 05
146
05
SF05 CF03
25000 FT XEQ10, 139 XEQ11 XEQ13 XEQ14
GTO 16
LBL 06
156
06
SF06
15000 FT XEQ10, 69 XEQ24, 49 XEQ11, 5000 FT XEQ10, 39 XEQ11
GTO 16
LBL 07
169
07
SF07 CF08
15000 FT XEQ10, 139 XEQ24, 99 XEQ11, 5000 FT XEQ10, 59 XEQ11
GTO 16
LBL 16
221
16
C
SEA LEVEL XEQ10, 0 XEQ11
NOTE: Flow does not necessarily progress thru to 16. The program can branch and skip to 17 by successful logic qualification at the second level of operation in each configuration branch. Branch out can occur in the XEQ11/LBL11 constructs.
LBL 17
226
17
D
Calculation of address factors to be used in indirect addressing to locate FR,TR value in data set.
228
101 > DIST TO GO?
YES
NO
LBL 18
247
(DTG/10) - INT(DTG/10) = f
STO 02
INT(DTG/10) + 0 = pa
232
201 > DIST TO GO?
YES
NO
LBL 19
259
(DTG/20) - INT(DTG/20) = f
STO 02
INT(DTG/20) + 5 = pa
235
(DTG/50) - INT(DTG/50) = f
STO 02
INT(DTG/50) + 11 = pa
E
DTG - DIST TO GO
f - interpolation factor
INT - integer function
pa - preliminary address

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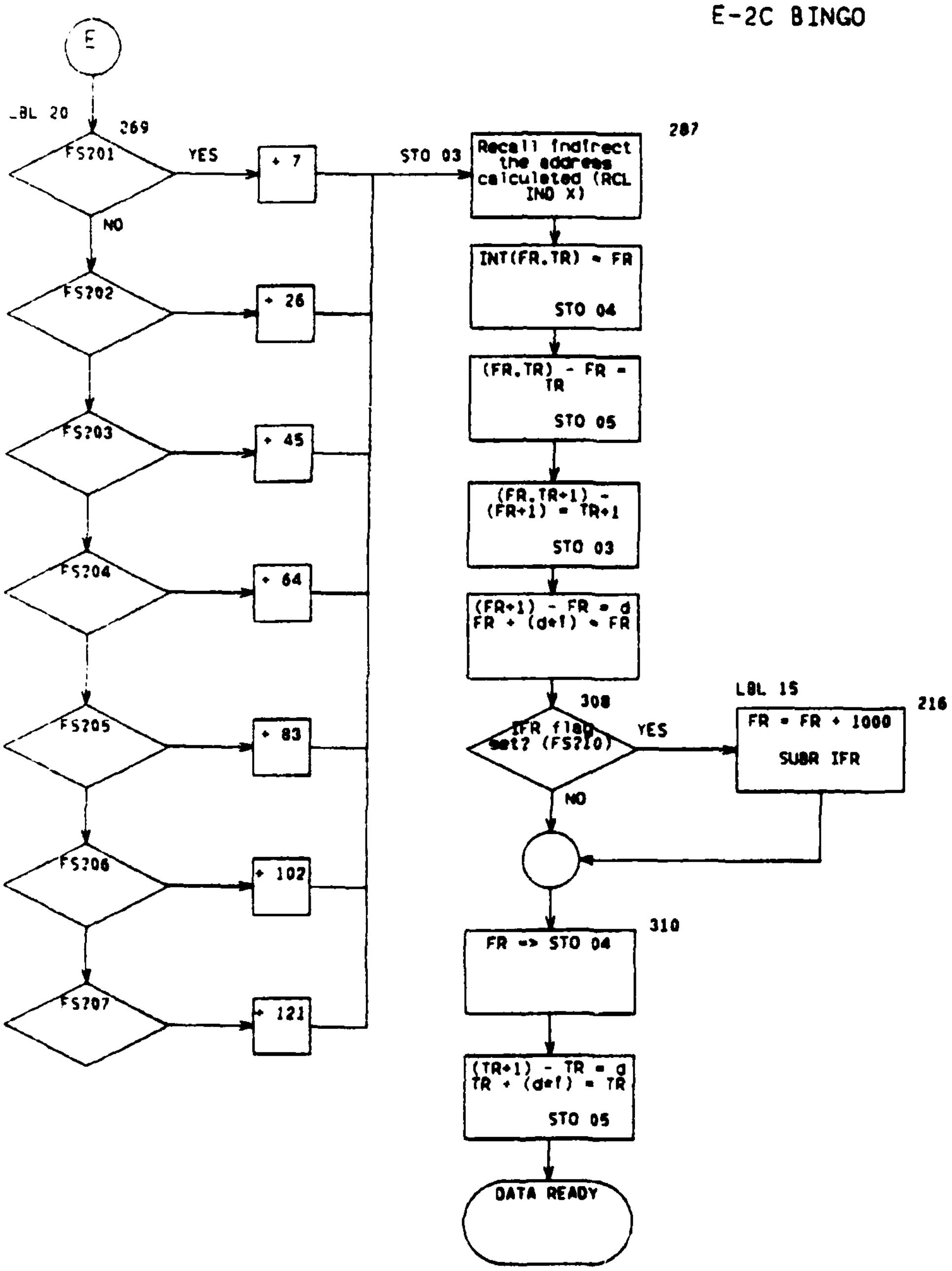
E-2C BINGO


E
LBL 20
269
FS?01
YES
NO
+ 7
STO 03
FS?02
+ 26
FS?03
+ 45
FS?04
+ 64
FS?05
+ 83
FS?06
+ 102
FS?07
+ 121
287
Recall indirect the address calculated (RCL IND X)
INT(FR.TR) = FR
STO 04
(FR.TR) - FR = TR
STO 05
(FR.TR+1) - (FR+1) = TR+1
STO 03
(FR+1) - FR = d
FR + (d*f) = FR
308
IFR flag set? (FS?10)
YES
NO
LBL 15
216
FR = FR + 1000
SUBR IFR
310
FR => STO 04
(TR+1) - TR = d
TR + (d*f) = TR
STO 05
DATA READY

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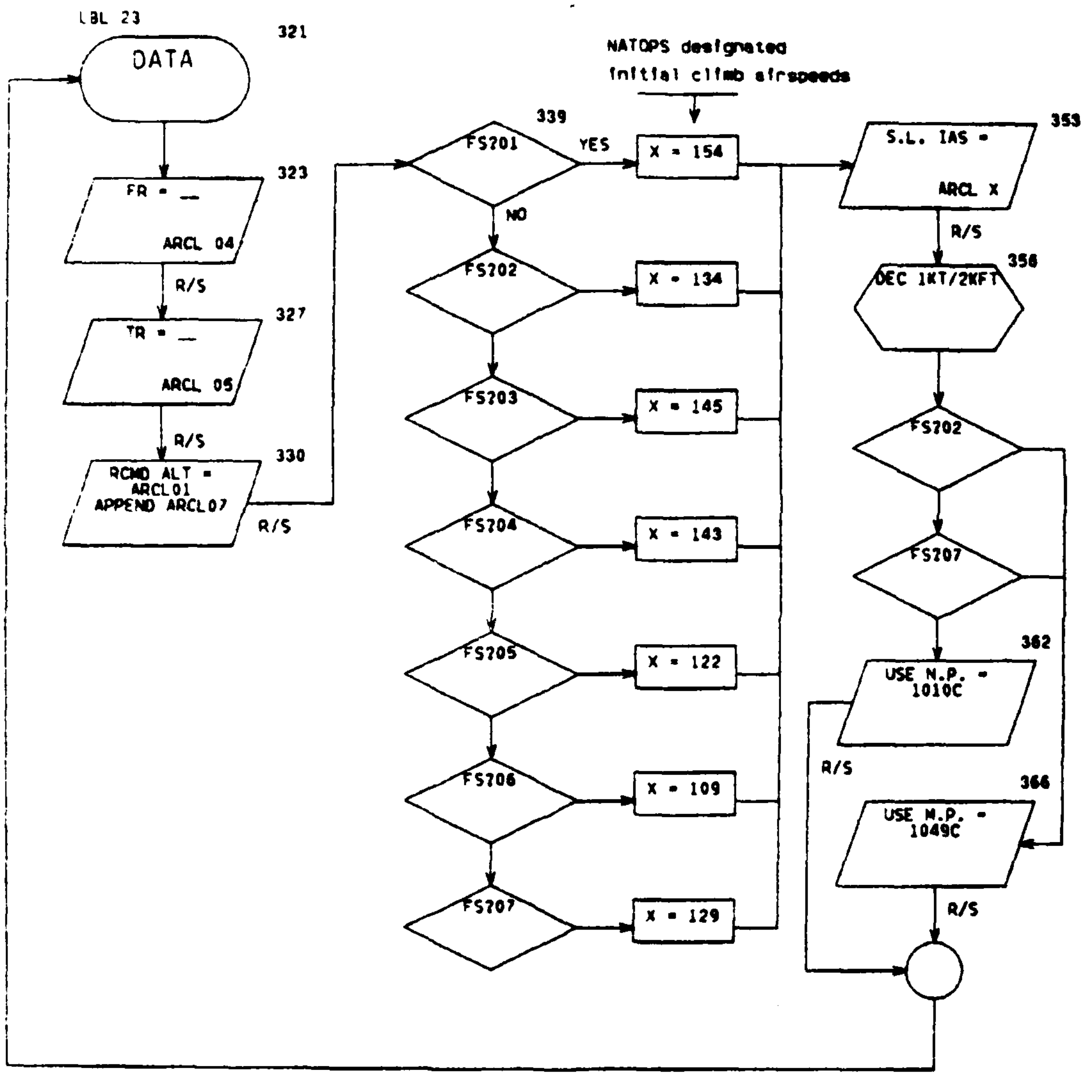
E-2C BINGO



LBL 23
DATA
321
FR = __
ARCL 04
323
R/S
TR = __
ARCL 05
327
R/S
RCMD ALT =
ARCL01
APPEND ARCL07
330
R/S
NATOPS designated
initial climb airspeeds
339
FS201
YES
NO
X = 154
FS202
X = 134
FS203
X = 145
FS204
X = 143
FS205
X = 122
FS206
X = 109
FS207
X = 129
S.L. IAS =
ARCL X
353
R/S
DEC 1KT/2KFT
356
FS202
FS207
USE N.P. =
1010C
362
R/S
USE N.P. =
1049C
366
R/S

E-2C BINGO/HP-41CV Code (June 1982, 1/4)

```
01♦LBL "STB"
02 CF 01
03 CF 02
04 CF 03
05 CF 04
06 CF 05
07 CF 06
08 CF 07
09 "**E2C BINGO*"
10 AVIEW
11 PSE
12 "DIST TO GO ?"
13 PROMPT
14 STO 00
15 "SELECT.."
16 AVIEW
17 PSE
18 "ENGS, GR, FLPS"
19 PROMPT
20♦LBL B
21 CF 02
22 "2 ENGS"
23 PROMPT
24♦LBL G
25 SF 08
26 "SINGLE ENG..."
27 AVIEW
28 PSE
29 "**WARNING**"
30 AVIEW
31 "SE=GU,FU,ONLY.."
32 AVIEW
33 PSE
34 GTO 08
35♦LBL C
36 SF 03
37 "GEAR UP"
38 PROMPT
39♦LBL H
40 CF 03
41 "GEAR DOWN.."
42 AVIEW
43 PSE
44 "SELECT.."
45 AVIEW
46 PSE
47 "FU/FD ONLY"
48 PROMPT
49♦LBL D
50 CF 06
51 CF 07
52 CF 08
53 SF 05
54 "FLAPS UP.."
55 AVIEW
56 PSE
57 GTO 08
58♦LBL I
59 CF 05
60 CF 07
61 CF 08
62 SF 06
63 "FLAPS 1/3.."
64 AVIEW
65 PSE
66 GTO 08
67♦LBL "F23"
68 CF 05
69 CF 06
70 CF 08
71 SF 07
72 "FLAPS 2/3.."
73 AVIEW
74 PSE
75 GTO 08
76♦LBL "FD"
77 CF 05
78 CF 06
79 CF 07
80 CF 08
81 "FLAPS DOWN..."
82 AVIEW
83 PSE
84♦LBL 08
85 " VFR, IFR ?"
86 PROMPT
87♦LBL E
88 GTO 09
89♦LBL J
90 SF 10
91♦LBL 09
92 FS? 08
93 GTO 07
94 FS? 03
95 GTO 22
96 FS? 05
97 GTO 02
98 GTO 06
99♦LBL 22
100 FS? 05
101 GTO 01
102 FS? 06
103 GTO 03
104 FS? 07
105 GTO 04
106 GTO 05
107♦LBL 01
108 SF 01
109 CF 03
110 CF 05
111 XEQ 12
112 XEQ 13
113 XEQ 14
114 GTO 16
115♦LBL 02
116 CF 05
117 SF 02
118 "20000 FT"
119 XEQ 10
120 69
121 XEQ 24
122 39
123 XEQ 11
124 GTO 16
125♦LBL 03
126 CF 06
127 XEQ 12
128 XEQ 13
129 XEQ 14
130 GTO 16
131♦LBL 04
132 CF 07
133 CF 03
134 SF 04
135 "25000 FT"
136 XEQ 10
137 119
138 XEQ 11
139 "20000 FT"
140 XEQ 10
141 79
142 XEQ 24
143 39
144 XEQ 11
145 GTO 16
146♦LBL 05
147 CF 03
148 SF 05
149 "25000 FT"
150 XEQ 10
```

E-2C BINGO/HP-41CV Code (June 1982, 2/4)

```
139
XEQ 11
XEQ 13
XEQ 14
GTO 16
◆LBL 06
SF 06
"15000 FT"
XEQ 10
69
XEQ 24
49
XEQ 11
" 5000 FT"
XEQ 10
39
XEQ 11
GTO 16
◆LBL 07
CF 08
SF 07
"15000 FT"
XEQ 10
139
XEQ 24
99
XEQ 11
" 5000 FT"
XEQ 10
59
XEQ 11
GTO 16
◆LBL 10
ASTO 01
ASHF
ASTO 07
RTN
◆LBL 11
RCL 00
X>Y?
GTO 17
RTN
◆LBL 24
XEQ 11
"10000 FT"
XEQ 10
RTN
◆LBL 12
"30000 FT"
XEQ 10
139
XEQ 11
RTN
◆LBL 13
"20000 FT"
XEQ 10
69
XEQ 11
RTN
◆LBL 14
"10000 FT"
XEQ 10
49
XEQ 11
RTN
◆LBL 15
CF 10
1000
+
RTN
◆LBL 16
"  SEA LEVEL"
XEQ 10
0
XEQ 11
◆LBL 17
RCL 00
101
X>Y?
GTO 18
X<>Y
201
X>Y?
GTO 19
RCL 00
50
/
ENTER↑
INT
STO 03
-
STO 02
RCL 03
11
GTO 20
◆LBL 18
RCL 00
10
/
ENTER↑
INT
STO 03
-
STO 02
RCL 03
0
GTO 20
◆LBL 19
RCL 00
20
/
ENTER↑
INT
STO 03
-
STO 02
RCL 03
5
◆LBL 20
+
FS? 01
7
FS? 02
26
FS? 03
45
FS? 04
64
FS? 05
83
FS? 06
102
FS? 07
121
+
STO 03
RCL IND X
ENTER↑
INT
STO 04
-
STO 05
1
ST+ 03
RCL IND 03
ENTER↑
INT
STO 06
-
STO 03
```

E-2C BINGO/HP-41CV Code (June 1982, 3/4)

```
301 RCL 06
302 RCL 04
303 -
304 RCL 02
305 *
306 RCL 04
307 +
308 FS? 10
309 XEQ 15
310 STO 04
311 RCL 03
312 RCL 05
313 -
314 RCL 02
315 *
316 RCL 05
317 +
318 10
319 *
320 STO 05
321♦LBL 21
322♦LBL 23
323 FIX 0
324 " FR = "
325 ARCL 04
326 FIX 2
327 PROMPT
328 " TR = "
329 ARCL 05
330 PROMPT
331 "RCMD ALT ="
332 AVIEW
333 PSE
334 CLA
335 ARCL 01
336 "⊢"
337 ARCL 07
338 PROMPT
339 FIX 0
340 FS? 01
341 154
342 FS? 02
343 134
344 FS? 03
345 145
346 FS? 04
347 143
348 FS? 05
349 122
350 FS? 06
351 109
352 FS? 07
353 129
354 "S.L. IAS = "
355 ARCL X
356 PROMPT
357 "DEC 1KT/2KFT"
358 PROMPT
359 FS? 02
360 GTO 38
361 FS? 07
362 GTO 38
363 "USE M.P.=1010C"
364 PROMPT
365 GTO 23
366♦LBL 38
367 "USE M.P.=1049C"
368 PROMPT
369 GTO 23
370 .END.
```

```
R00=  0.000
R01=  1.000
R02=  2.000
R03=  3.000
R04=  4.000
R05=  5.000
R06=  6.000
R07=  7.000
R08=  1,240.003
R09=  1,380.006
R10=  1,515.009
R11=  1,655.012
R12=  1,760.015
R13=  1,865.018
R14=  1,950.020
R15=  2,040.023
R16=  2,120.025
R17=  2,200.028
R18=  2,365.033
R19=  2,525.038
R20=  2,665.042
R21=  2,810.047
R22=  2,945.052
R23=  3,300.103
R24=  3,655.115
R25=  4,015.126
R26=  4,375.138
R27=  1,275.004
R28=  1,460.007
R29=  1,640.010
R30=  1,800.014
R31=  1,940.017
R32=  2,080.020
R33=  2,210.024
R34=  2,325.027
R35=  2,435.030
R36=  2,545.033
R37=  2,775.039
R38=  3,000.045
R39=  3,225.051
R40=  3,465.057
R41=  3,695.103
R42=  4,265.118
R43=  4,845.133
R44=  5,430.148
R45=  6,020.204
R46=  1,250.003
R47=  1,400.006
R48=  1,545.009
R49=  1,685.012
R50=  1,795.015
R51=  1,905.018
R52=  2,015.021
R53=  2,105.024
R54=  2,195.027
R55=  2,280.030
R56=  2,460.036
R57=  2,620.040
R58=  2,775.045
R59=  2,925.050
R60=  3,080.055
R61=  3,465.107
R62=  3,860.120
R63=  4,245.133
R64=  4,630.145
R65=  1,250.003
R66=  1,400.007
R67=  1,550.010
R68=  1,685.013
R69=  1,800.016
R70=  1,915.019
R71=  2,035.022
R72=  2,130.025
R73=  2,220.028
R74=  2,310.031
R75=  2,490.036
```

E-2C BINGO/HP-41CV Code (June 1982, 4/4)

```
R76=  2,660.041
R77=  2,835.047
R78=  3,010.052
R79=  3,185.058
R80=  3,625.112
R81=  4,060.126
R82=  4,495.139
R83=  4,945.153
R84=  1,280.004
R85=  1,465.008
R86=  1,650.012
R87=  1,810.015
R88=  1,960.019
R89=  2,100.023
R90=  2,250.026
R91=  2,365.029
R92=  2,485.033
R93=  2,605.036
R94=  2,840.042
R95=  3,075.048
R96=  3,300.054
R97=  3,530.101
R98=  3,760.107
R99=  4,340.123
R100=  4,910.139
R101=  5,510.155
R102=  6,120.211
R103=  1,310.004
R104=  1,530.008
R105=  1,750.013
R106=  1,950.017
R107=  2,130.021
R108=  2,310.025
R109=  2,470.029
R110=  2,625.032
R111=  2,780.036
R112=  2,945.040
R113=  3,270.048
R114=  3,590.055
R115=  3,915.103
R116=  4,235.110
R117=  4,555.117
R118=  5,365.136
R119=  6,210.155
R120=  9,999.999
R121=  9,999.999
R122=  1,210.004
R123=  1,320.008
R124=  1,430.011
R125=  1,540.015
R126=  1,650.019
R127=  1,750.023
R128=  1,850.026
R129=  1,950.029
R130=  2,050.033
R131=  2,145.037
R132=  2,330.043
R133=  2,495.050
R134=  2,670.056
R135=  2,845.103
R136=  3,025.109
R137=  3,475.125
R138=  3,920.142
R139=  4,360.157
R140=  4,810.214
```

3.3 THE E-2C CROSSWIND LANDING LIMITATIONS PROGRAM

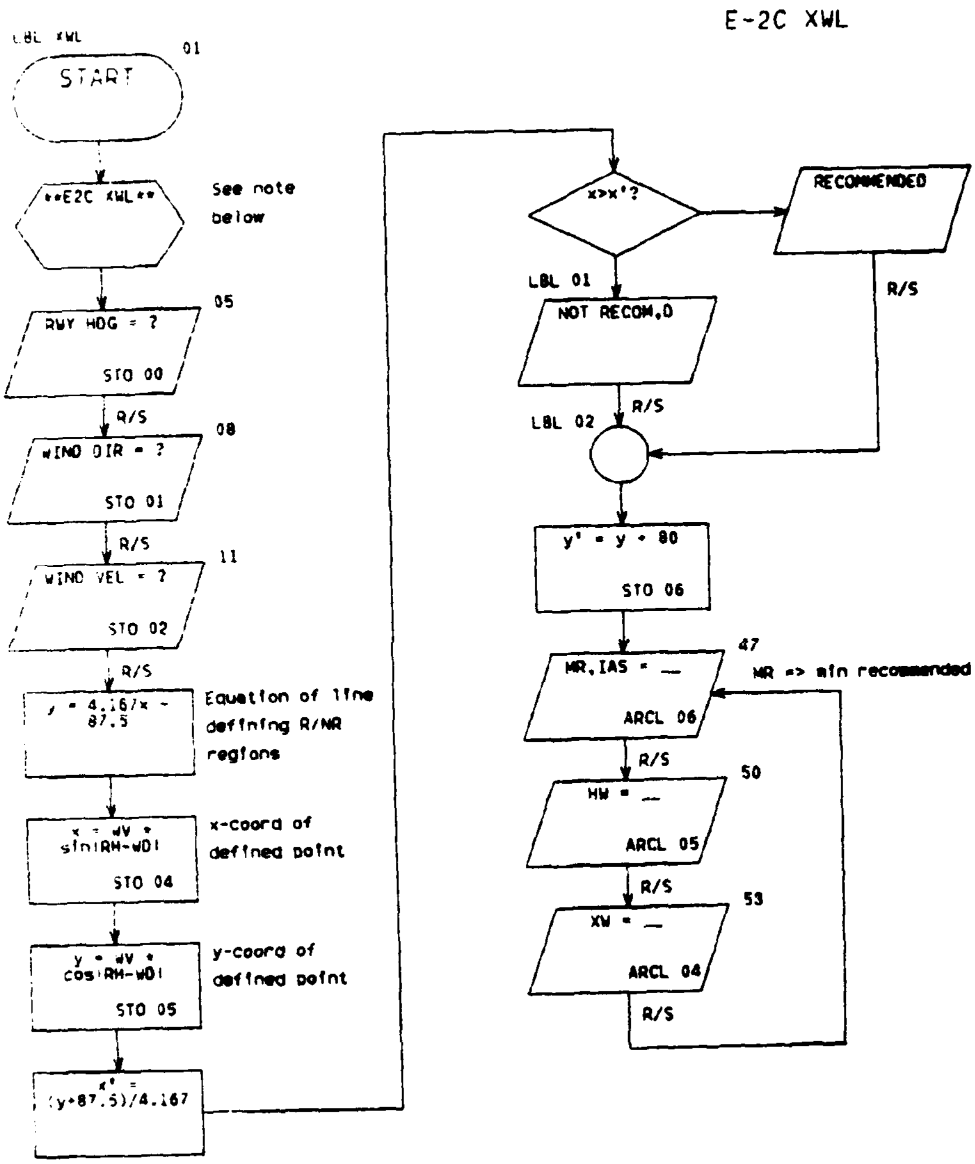
The Crosswind Landing Limitations program is a straight forward interpretation of the Takeoff and Landing Crosswind Limits chart on page 11-26 of the E-2C NATOPS manual. Subsequently, it was determined that the same chart is used for the E-2B and C-2A; hence, the code for those aircraft is exactly the same except for the label that appears in the calculator readout when the program is initially selected. A separate section for the E-2B and C-2A programs is not included.

3.3.1 Theory of Operation

The XWL program loads from extended memory in less than 10 seconds. The press key 33 and observe "**E-2C XWL** appear momentarily in the display.[11] Assuming the program is being used during the setup to landing from an approach or during a VFR touch and go pattern, the user is then asked for "RWY HDG = ?" (runway heading). Enter the correct number (010 to 360) followed by R/S. In the same manner, the program asks for "WIND DIR = ?" and "WIND VEL = ?". The program computes x and y positions based on the input parameters then compares these against an equation for the line defining the boundary between recommended and not recommended. Depending on the outcome of the logic, the program will then, obviously, display "RECOMMENDED" or "NOT RECOM,D". The program then computes minimum recommended IAS for touch-

[11] Or "**E-2B XWL**" or "**C-2A XWL**" as previously noted.

down (MR,IAS), headwind (HW) and crosswind (XW) and displays each. The flowchart and code for the program are listed on the following pages.



Note: Program for E-2B and C-2A is the same in all respects except for the viewer label.

E-2C XWL/HP-41CV Code (June 1982, 1/1)

```
01♦LBL "XWL"
02 "**E-2C XWL**"
03 AVIEW
04 PSE
05 "RWY HDG = ?"
06 PROMPT
07 STO 00
08 "WIND DIR = ?"
09 PROMPT
10 STO 01
11 "WIND VEL = ?"
12 PROMPT
13 STO 02
14 RCL 00
15 RCL 01
16 -
17 ABS
18 STO 03
19 SIN
20 RCL 02
21 *
22 STO 04
23 RCL 03
24 COS
25 RCL 02
26 *
27 STO 05
28 87.5
29 +
30 4.167
31 /
32 RCL 04
33 X>Y?
34 GTO 01
35 "RECOMMENDED"
36 PROMPT
37 GTO 02
38♦LBL 01
39 "NOT RECOM,D"
40 PROMPT
41♦LBL 02
42 RCL 05
43 80
44 +
45 STO 06
46 FIX 0
47 "MR,IAS = "
48 ARCL 06
49 PROMPT
50 " HW = "
51 ARCL 05
52 PROMPT
53 " XW = "
54 ARCL 04
55 PROMPT
56 GTO 02
57 .END.
```

3.4 SAMPLE PROGRAM OPERATION

The best way to understand operation of the calculator is to create a scenario in which the calculator might be used. The following scene is typical of what might be expected.

3.4.1 Using the FPAS Program

Assume the mission is complete, marshall instructions have been received, and the aircraft is proceeding to the assigned holding fix with an expected push time. Approximate distance from present position to the holding fix is sufficient to justify calculating a max range profile. The copilot, most probable operator of the calculator, turns the HP-41 on and ensures that USER mode appears in the window. The FPAS program is selected by SHIFT/KEY[12]11. The program operation symbol (a flying "duck") appears in the window while the FPAS program loads from extended memory to main memory. Upon completion of the load sequence, the windown again displays whatever numbers were in the window to begin with.

KEY 11 is now pushed again to start the program. "**E2C FPAS**" appears momentarily in the window as an echo check verification, followed by "BASIC WT = ?". Enter 39600, then R/S. The other prompts occur as follows.

Prompt	Response
CARGO WT = ?	50 R/S
NO. CREW = ?	5 R/S

[12] The yellow SHIFT key doubles the USER functions of each of the program selecting keys. KEY 11 is also the START key for programs in the unshifted mode.

PROFILE?	RANGE	KEY 12
MAX RANGE	(momentary echo check)	
ALT = FT?	25000	R/S
OAT = C?	-15	R/S (key CHS for +/-)
IAS = KTS?	155	R/S (current IAS)
FUEL = LBS?	6500	R/S (read from gages)
GS/AVAIL? Y/N	YES	KEY 15 (assuming CAINS up)
GS = KTS?	250	R/S
DATA READY		Press R/S or KEY 21 to continue
*RCMD MR IAS		
*PRESENT ALT		
*MR IAS = 169		R/S
*MR TAS = 265		R/S
*HW = -7		R/S (a tail wind)
RCMD CRS CLG		
CC = 27100		R/S
GW = 47150		
UPDATE @ 30M		R/S to repeat data

The pilot now establishes IAS = 169 knots to fly max range fuel consumption to the marshall holding point. En-route, the copilot accesses the max endurance program to plan a holding airspeed.[13] KEY 13 is pressed and the following sequence of commands and responses occur.

Prompt	Response	
**MAX ENDUR*		
ALT = FT?	25000	R/S
OAT = C?	-15	R/S

[13] The traditional method of flying max endurance is to set 21 to 22 units angle of attack. The AOA probe, however, is a pressure differential device that measures pressure at two positions on the surface of a small cylinder. It is least accurate at slower airspeeds because of lower static pressures and stiction in the mechanism. There is also a caution in the NATOPS regarding reverse power effects (ie, back side of power curve) at 22uAOA. Since the airspeed indicators are more accurate in a steady state condition, it is recommended that an output of MEIAS-to-fly be used in preference to an AOA setting.

IAS = KTS?	169	R/S
FUEL = LBS?	9000	R/S
DATA READY		R/S or KEY 21
+RCMD ME IAS		
+PRESENT ALT		
+ME IAS= 126		R/S
GW = 49650		R/S
UPDATE @ 30M		R/S to repeat data

The pilot enters holding and establishes 126 knots IAS and cross checks with the AOA. (This airspeed is based on a 9000 pound fuel load and should be updated periodically if a long period in holding occurs. ME IAS is strictly a function of gross weight).

3.4.2 Using the BINGO Program

In holding, the copilot now accesses the BINGO program by pressing SHIFT/KEY 21. When loaded, the START key (11) is pressed.[14]

Prompt	Response	
**E2C BINGO*		
DIST TO GO ?	90	R/S
SELECT..		
ENGS, GR, FLAPS	2E	KEY 12
2 ENGS	GU	KEY 13
GEAR UP	FU	KEY 14
FLAPS UP..		
VFR, IFR ?	IFR	KEY 25
"Traveling duck"		
FR = 3120		R/S (3120 lbs fuel req'd)
TR = 0.25		R/S (25 min enroute)

[14] Assume a BINGO distance of 90 miles has been assigned by marshall. The ship and BINGO field are IFR. The anticipated aircraft configuration is two engines, gear up, and flaps up.

```
RCMD ALT =
20000 FT                  R/S
S.L. IAS = 154            R/S (initial IAS to
                               start climb)
DEC 1KT/2KFT              R/S (decrease IAS
                               1 knot/2000ft climb)
USE N.P.=1010C            R/S to repeat data
```

This data is duly recorded for possible use later in the recovery. Commencing the approach, fuel is dumped down to appropriate landing weight. Enroute, the E-2 is vectored in the usual manner to allow preceeding aircraft to clear the bolter pattern. Shortly after setting the approach configuration, the aircraft just prior to the E-2 manages to foul the deck indefinitely. A bolter is anticipated for the E-2. Upon cleaning up, the pilot experiences a jammed landing gear handle that precludes raising the gear. The flaps come up satisfactorily. Again, the BINGO program is accessed.

Prompt	Response
**E2C BINGO*	
DIST TO GO ?	90 R/S
SELECT..	
ENGS, GR, FLPS	2E
2 ENGS	GD
GEAR DOWN..	
SELECT..	
FU/FD ONLY	FU
FLAPS UP..	
VFR, IFR ?	IFR
"Traveling Duck"	
FR = 3435	R/S
TR = 0.30	R/S
RCMD ALT =	

20000 FT	R/S
S.L. IAS = 134	R/S
DEC 1KT/2KFT	R/S
USE M.P.=1049C	R/S to repeat data

Clearance to BINGO is received, and during the climb, one of the crew produces a screw driver that frees the landing gear handle. The gear come up and the pilot reestablishes a clean configuration.

3.4.3 The FPAS Program Again

Leveling off at 20000 feet, the FPAS program is accessed once more. The following max range data is obtained.

Prompt	Response	
	START	KEY 11
E2C FPAS		
BASIC WT = ?	39600	R/S
CARGO WT = ?	50	R/S
NO.CREW/PAX=?	5	R/S
PROFILE?	RANGE	KEY 12
MAX RANGE		
ALT = FT?	20000	R/S
OAT = C?	-10	R/S
IAS = KTS?	165	R/S
FUEL = LBS?	4500	R/S
GS,AVAIL? Y/N	NO	(CAINS is down)
INPUT WINDS..		
WIND DIR = ?	025	R/S (forecast or last known)
WIND VEL = ?	50	R/S
A/C HDG = ?	090	R/S
DATA READY		
*RCMD MR IAS		
*PRESENT ALT		
*MR IAS= 181		R/S
*MR TAS= 259		R/S
*HW = 21		R/S

RCMD CRS CLG	
CC = 29300	R/S
GW = 45150	R/S
UPDATE @ 30M	R/S to repeat data

The pilot elects to remain at 20000 feet, anticipating higher winds at higher altitude, and calls for the max range descent program. The following responses are obtained.

Prompt	Response
	DESCENT KEY 14
MR DESCENT	
ALT = FT?	20000 R/S (altitude to descend from)
FUEL = LBS?	4000 R/S (anticipated)
L/O ALT = ?	2000 R/S (approach mda)
"Traveling Duck"	
DSNT,DIST=42	R/S
** NOTE **	
BELOW 10K FT	
INC MRD IAS	
1 KT/1000FT	
USE 500 SHP	
MRD IAS=156	R/S to repeat data

3.4.4 The Crosswind Landing Limitations Program

Checking in with approach the pilot receives the following pertinent weather data: winds 240 at 30, gusting to 35, runway 200 in use. The XWL program is called.

Prompt	Response
	XWL KEY 33
E-2C XWL	
RWY HDG = ?	200 R/S
WIND DIR = ?	240 R/S
WIND VEL = ?	35 R/S

RECOMMENDED	R/S
MR,IAS = 107	R/S (min rcmd touch down speed)
HW = 27	R/S
XW = 22	R/S to repeat data

Chapter IV
THE E-2B/HP-41CV PROGRAMS

The E-2C program is the standardization format used to design programs for the E-2B and C-2A. Hence, a detailed explanation for programs for each of the other two aircraft is not included. The reader is urged to study the E-2C programs for details on theory of operation.

It is appropriate to mention at this point, however, that no significant changes have been made in the E-2B NATOPS manual, Chapter 11, since 1964. Engine modifications and a major propeller change have occured since then. Only experience will determine whether computed parameters in this program are valid.

4.1 THE E-2B FPAS PROGRAM

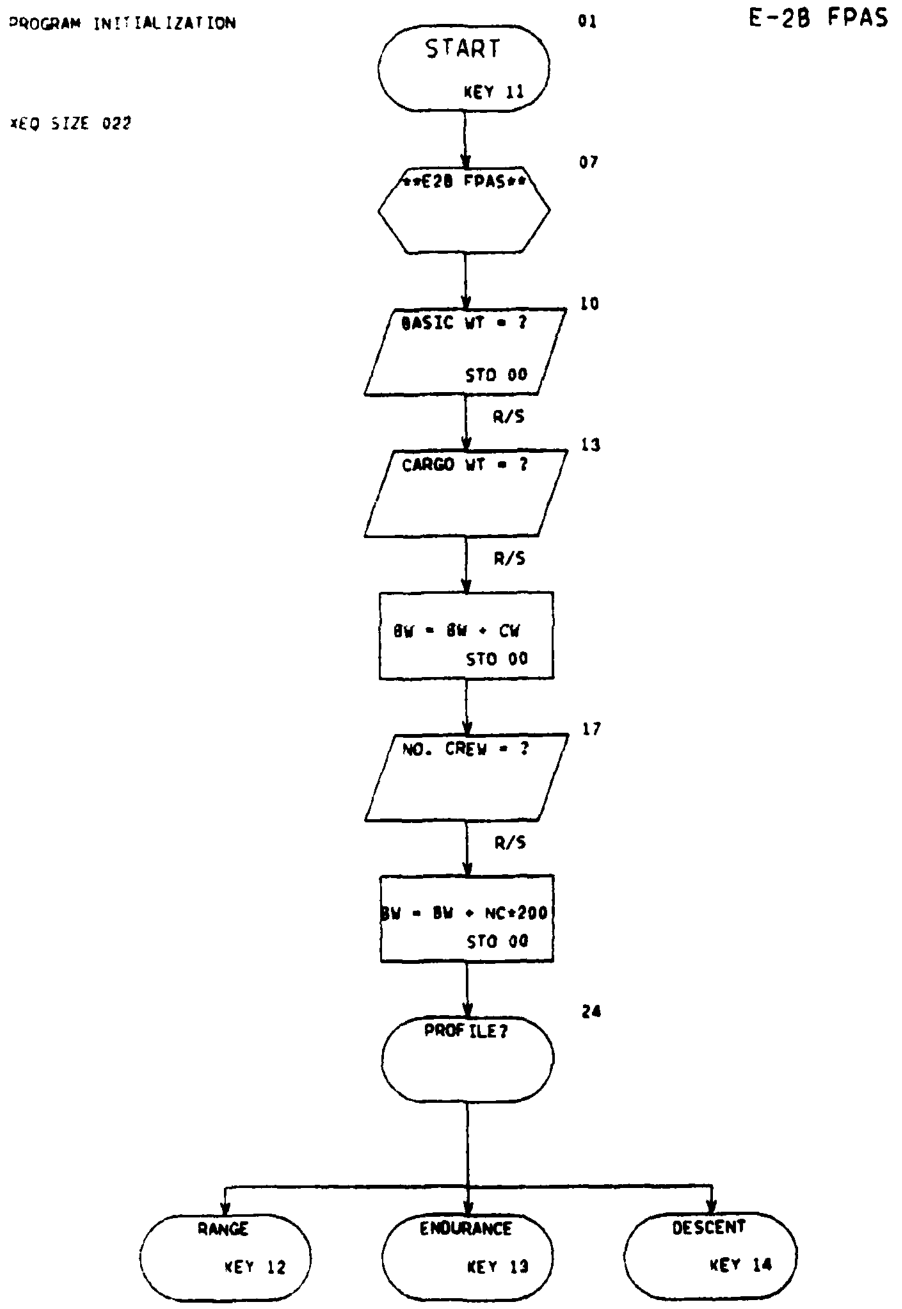
The major differences between the E-2B and E-2C programs are specific equations, listed at the end of this chapter, and the theory of operation of the descent profile for the E-2B.

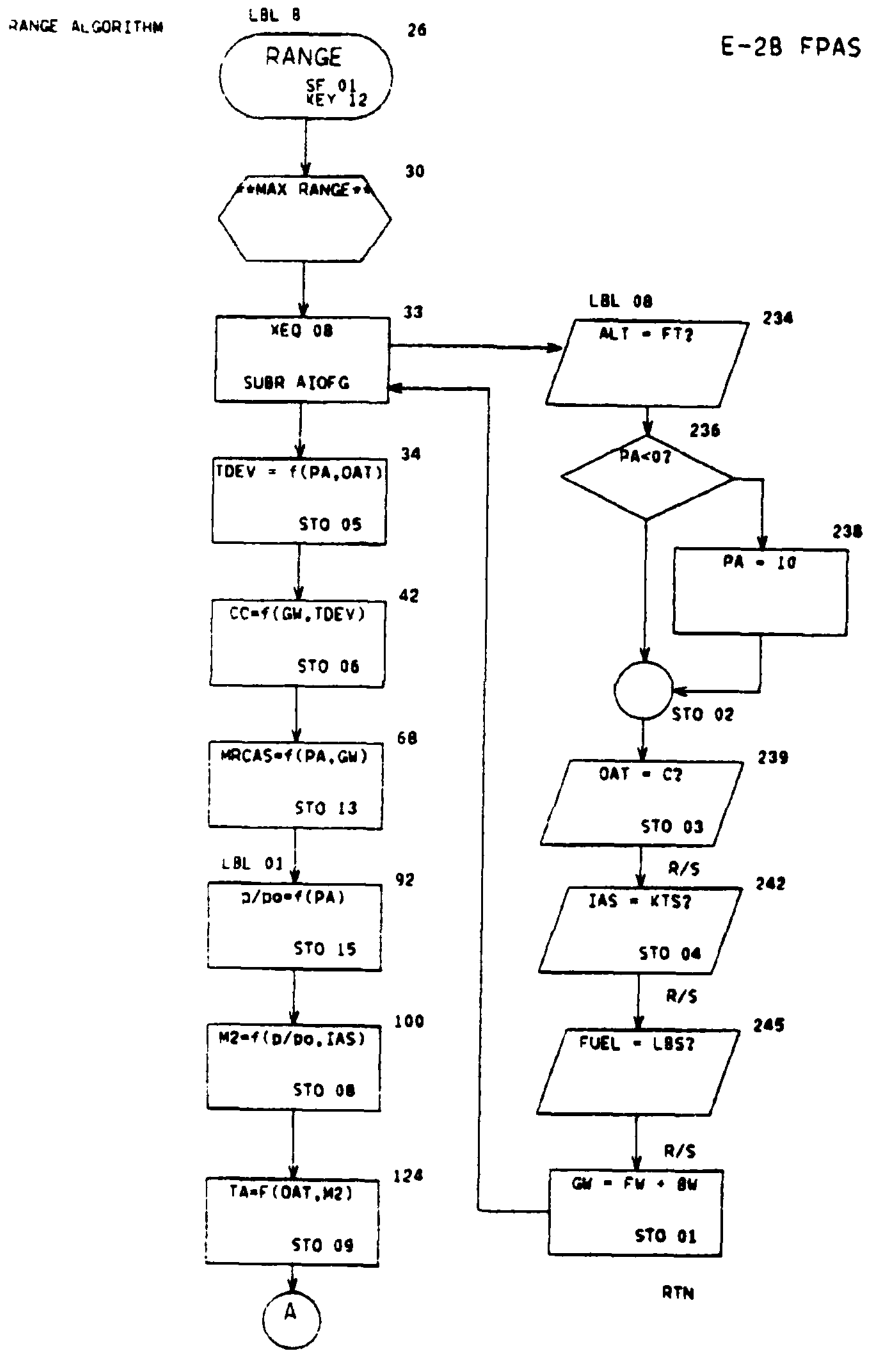
4.1.1 DESCENT

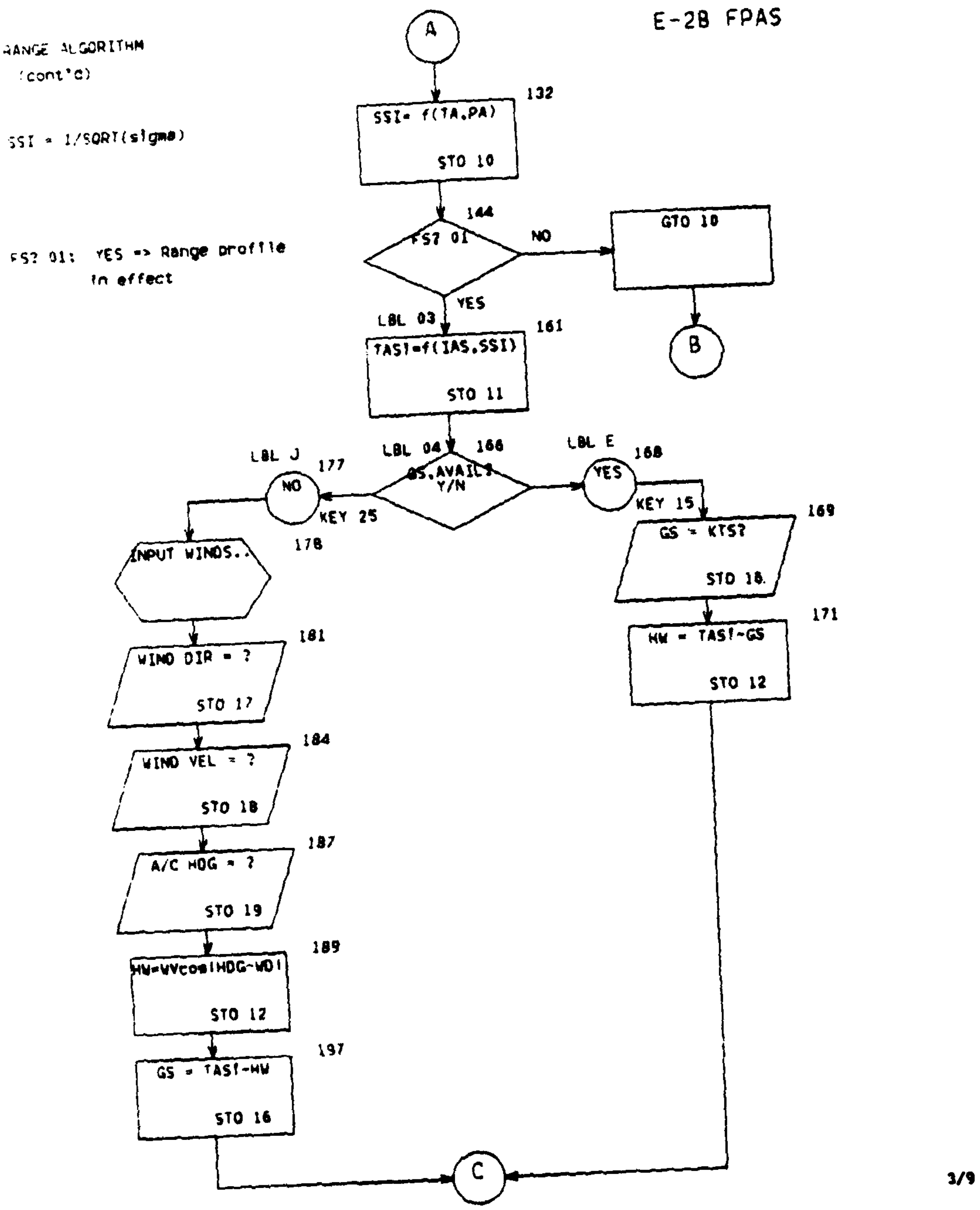
The max range descent IAS profile for the E-2C is dependent only on gross weight above 10000 feet, and on gross weight and altitude below 10000 feet. Program operation is dependent on selecting the correct starting altitude.

The E-2B (and C-2A) max range descent IAS profiles are exponential functions dependent on gross weight and altitude. Regression analysis yielded two sets of equations that split at 10000 feet to maintain accuracy. Program operation is transparent to the user, but the user is required to update the IAS at least once every 2000 feet during a descent.

The following pages document the flowchart and code for the E-2B FPAS.

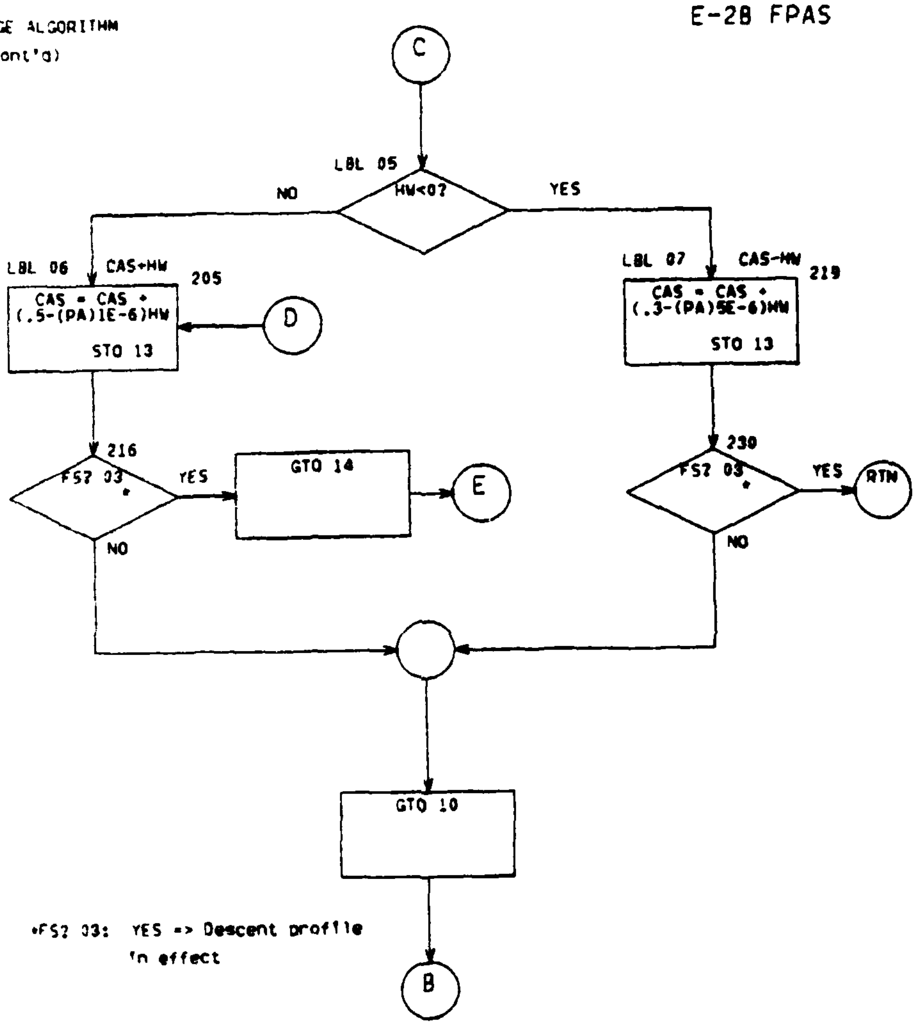

PROGRAM INITIALIZATION
E-2B FPAS
01
START
KEY 11
XEQ SIZE 022
07
E2B FPAS
10
BASIC WT = ?
STO 00
R/S
13
CARGO WT = ?
R/S
BW = BW + CW
STO 00
17
NO. CREW = ?
R/S
BW = BW + NC*200
STO 00
24
PROFILE?
RANGE
KEY 12
ENDURANCE
KEY 13
DESCENT
KEY 14


RANGE ALGORITHM
E-2B FPAS
LBL B
26
RANGE
SF 01
KEY 12
30
MAX RANGE
33
XEQ 08
SUBR AIOFG
34
TDEV = f(PA,OAT)
STO 05
42
CC=f(GW,TDEV)
STO 06
68
MRCAS=f(PA,GW)
STO 13
LBL 01
92
p/po=f(PA)
STO 15
100
M2=f(p/po,IAS)
STO 08
124
TA=F(OAT,M2)
STO 09
A
LBL 08
234
ALT = FT?
236
PA<0?
238
PA = 10
STO 02
239
OAT = C?
STO 03
R/S
242
IAS = KTS?
STO 04
R/S
245
FUEL = LBS?
R/S
GW = FW + BW
STO 01
RTN

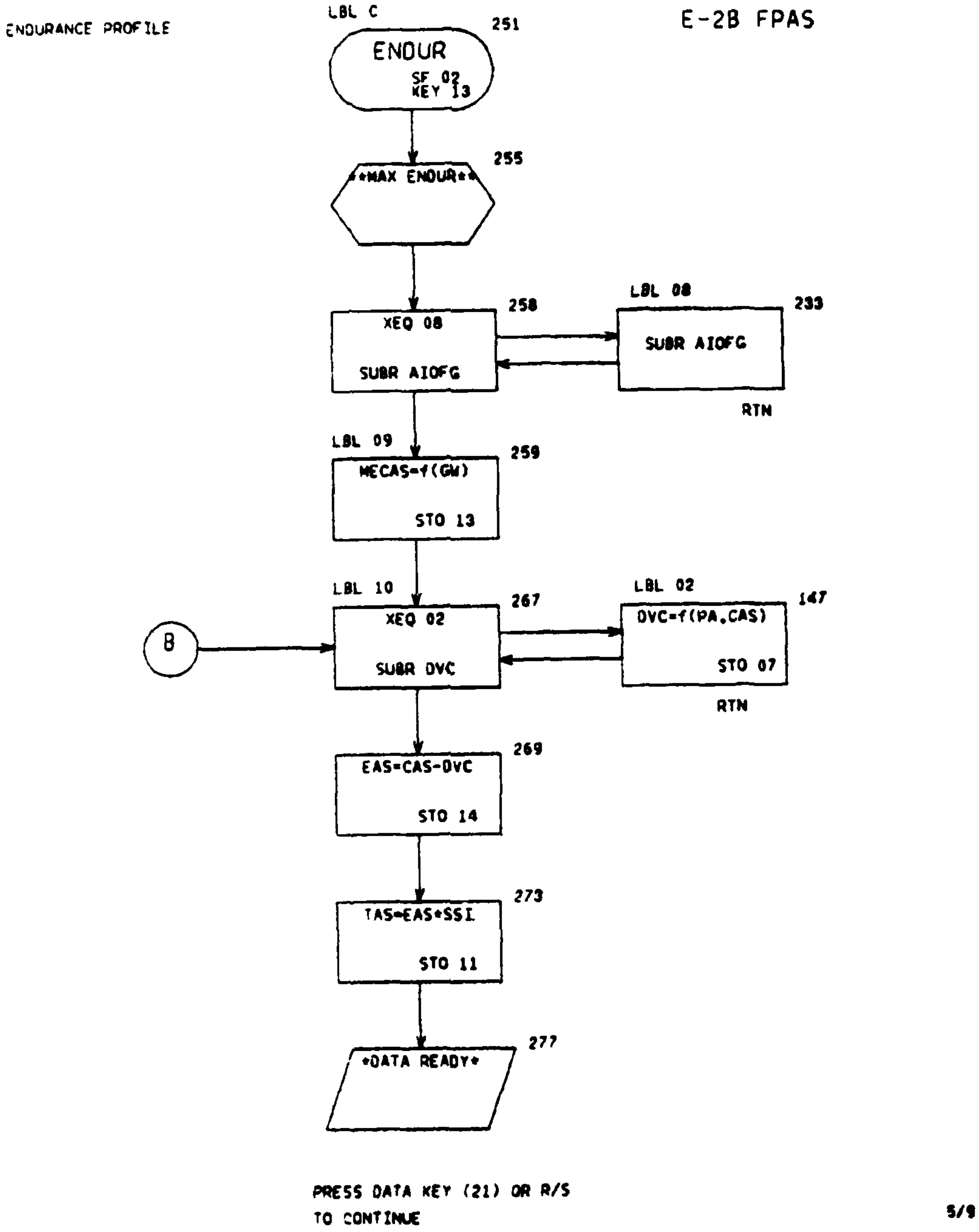

E-2B FPAS
RANGE ALGORITHM
(cont'd)
SSI = 1/SQRT(sigma)
FS? 01: YES => Range profile
in effect
A
SSI= f(TA,PA)
STO 10
132
FS? 01
144
NO
GTO 10
B
YES
LBL 03
TAS1=f(IAS,SSI)
STO 11
161
LBL 04
166
GS.AVAIL?
Y/N
LBL J
177
NO
KEY 25
LBL E
YES
168
KEY 15
GS = KTS?
STO 16
169
HW = TAS1-GS
STO 12
171
INPUT WINDS..
178
WIND DIR = ?
STO 17
181
WIND VEL = ?
STO 18
184
A/C HDG = ?
STO 19
187
HW=WVcos(HDG-WD)
STO 12
189
GS = TAS1-HW
STO 16
197
C

RANGE ALGORITHM
(cont'd)

E-28 FPAS

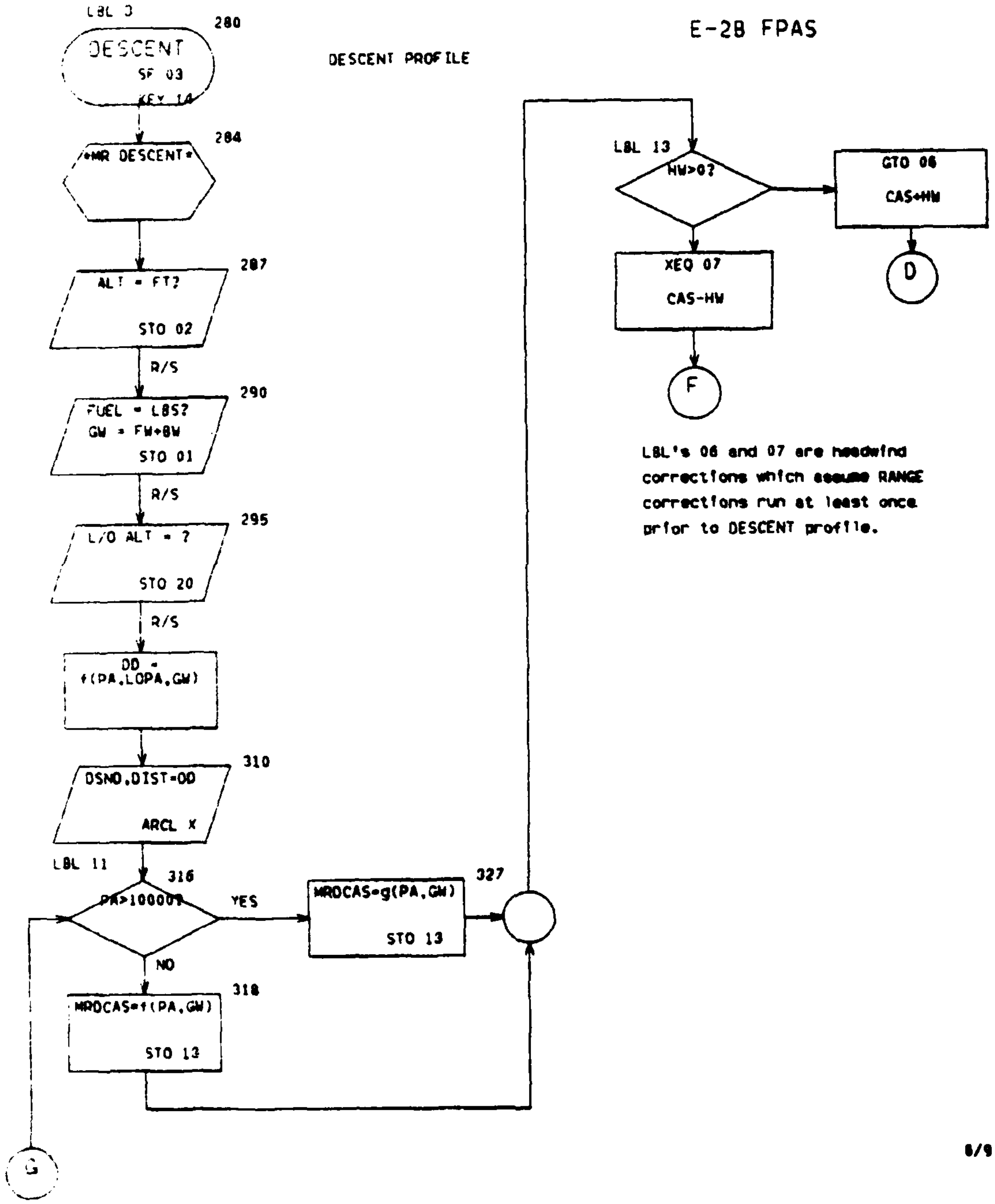


*FS? 03: YES => Descent profile in effect


ENDURANCE PROFILE
E-2B FPAS
LBL C
251
ENDUR
SF 02
KEY 13
255
MAX ENDUR
258
XEQ 08
SUBR AIOFG
LBL 08
233
SUBR AIOFG
RTN
LBL 09
259
MECAS=f(GW)
STO 13
LBL 10
267
XEQ 02
SUBR DVC
B
LBL 02
147
DVC=f(PA,CAS)
STO 07
RTN
269
EAS=CAS-DVC
STO 14
273
TAS=EAS*SSI
STO 11
277
DATA READY
PRESS DATA KEY (21) OR R/S
TO CONTINUE

E-2B FPAS

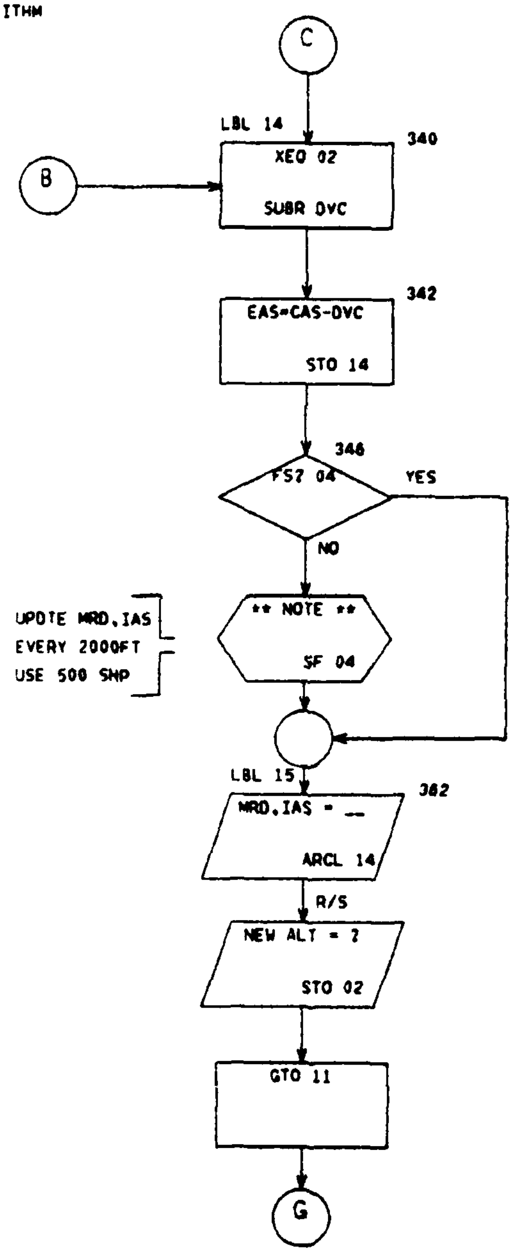
DESCENT PROFILE



LBL's 06 and 07 are headwind corrections which assume RANGE corrections run at least once prior to DESCENT profile.

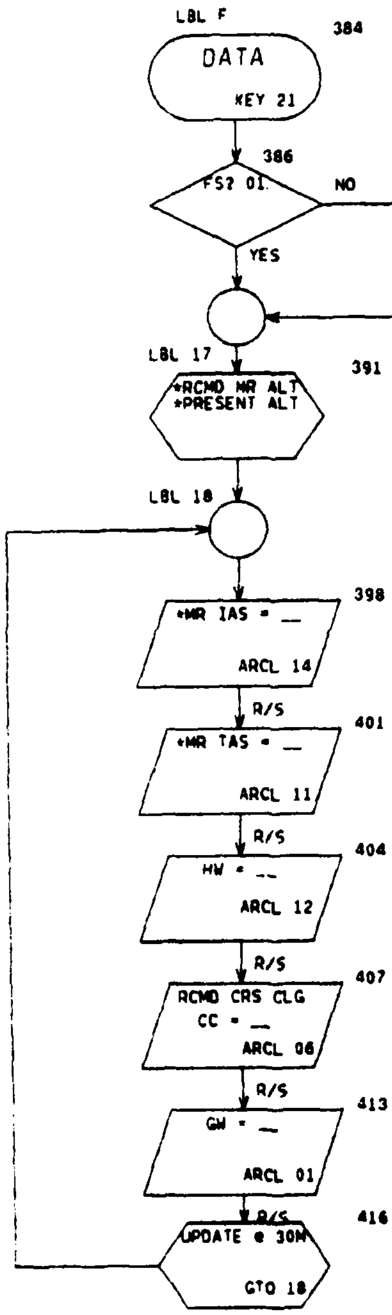
DESCENT ALGORITHM
(cont'd)

E-2B FPAS



DATA ALGORITHM

E-2B FPAS



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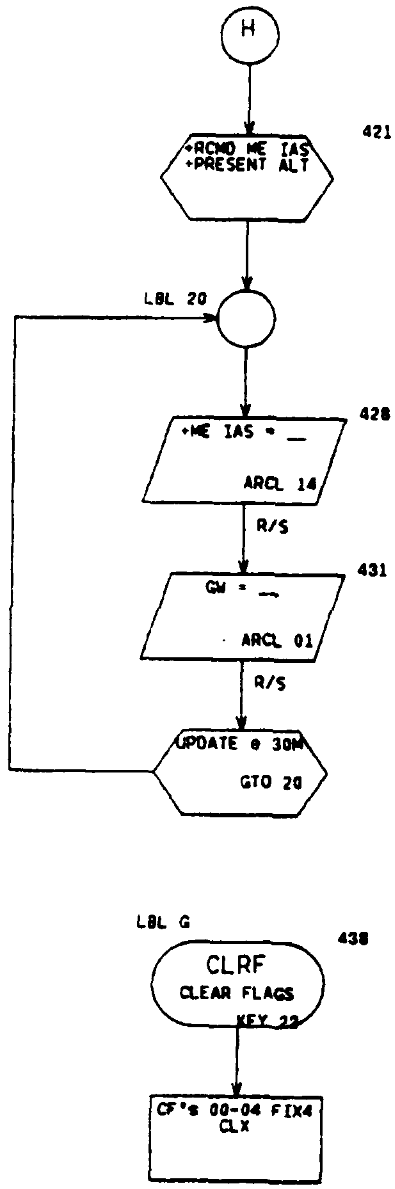
DATA ALGORITHM
(cont'd)

E-2B FPAS



E-2B FPAS/HP-41CV Code (June 1982; 1/3)

```
01♦LBL "STF"
02 CF 01
03 CF 02
04 CF 03
05 CF 04
06 CLRG
07 "**E2B FPAS**"
08 AVIEW
09 PSE
10 "BASIC WT = ?"
11 PROMPT
12 STO 00
13 "CARGO WT = ?"
14 PROMPT
15 +
16 STO 00
17 "NO. CREW = ?"
18 PROMPT
19 200
20 *
21 RCL 00
22 +
23 STO 00
24 "PROFILE?"
25 PROMPT
26♦LBL B
27 SF 01
28 CF 02
29 CF 03
30 "**MAX RANGE*"
31 AVIEW
32 PSE
33 XEQ 08
34 RCL 03
35 15
36 -
37 RCL 02
38 198 E-5
39 *
40 +
41 STO 05
42 30
43 RCL 05
44 -
45 -.0031
46 *
47 1
48 +
49 .705
50 RCL 01
51 *
52 *
53 CHS
54 30
55 RCL 05
56 -
57 78.67
58 *
59 +
60 58550
61 +
62 100
63 /
64 INT
65 100
66 *
67 STO 06
68 174.838
69 RCL 01
70 75 E-5
71 *
72 +
73 RCL 02
74 2522 E-6
75 *
76 -
77 RCL 01
78 RCL 02
79 5580656 E-15
80 *
81 *
82 +
83 RCL 02
84 X↑2
85 RCL 01
86 671 E-15
87 *
88 *
89 +
90 STO 13
91♦LBL 01
92 RCL 02
93 -6875 E-9
94 *
95 1
96 +
97 5.2563
98 Y↑X
99 STO 15
100 RCL 04
101 661.7
102 /
103 X↑2
104 .2
105 *
106 1
107 +
108 3.5
109 Y↑X
110 1
111 -
112 RCL 15
113 1/X
114 *
115 1
116 +
117 .286
118 Y↑X
119 1
120 -
121 5
122 *
123 STO 08
124 .2
125 *
126 1
127 +
128 1/X
129 RCL 03
130 *
131 STO 09
132 1936 E-6
133 *
134 RCL 02
135 1500
136 -
137 2112 E-8
138 *
139 +
140 E↑X
141 .982
142 *
143 STO 10
144 FS? 01
145 GTO 03
146 GTO 10
147♦LBL 02
148 RCL 02
149 91 E-6
150 *
```

E-2B FPAS/HP-41CV Code (June 1982; 2/3)

```
151 E↑X
152 1 E-7
153 *
154 RCL 13
155 2.852
156 Y↑X
157 *
158 STO 07
159 RTN
160♦LBL 03
161 RCL 04
162 RCL 10
163 *
164 STO 11
165♦LBL 04
166 "GS,AVAIL? Y/N"
167 PROMPT
168♦LBL E
169 "GS = KTS?"
170 PROMPT
171 STO 16
172 RCL 11
173 RCL 16
174 -
175 STO 12
176 GTO 05
177♦LBL J
178 "INPUT WINDS.."
179 AVIEW
180 PSE
181 "WIND DIR = ?"
182 PROMPT
183 STO 17
184 "WIND VEL = ?"
185 PROMPT
186 STO 18
187 "A/C HDG = ?"
188 PROMPT
189 STO 19
190 RCL 17
191 -
192 ABS
193 COS
194 RCL 18
195 *
196 STO 12
197 RCL 11
198 RCL 12
199 -
200 STO 16
201 RCL 12
202♦LBL 05
203 X<0?
204 GTO 07
205♦LBL 06
206 .5
207 RCL 02
208 1 E-5
209 *
210 -
211 RCL 12
212 *
213 RCL 13
214 +
215 STO 13
216 FS? 03
217 GTO 14
218 GTO 10
219♦LBL 07
220 .3
221 RCL 02
222 5 E-6
223 *
224 -
225 RCL 12
226 *
227 RCL 13
228 +
229 STO 13
230 FS? 03
231 RTN
232 GTO 10
233♦LBL 08
234 "ALT = FT?"
235 PROMPT
236 X<0?
237 10
238 STO 02
239 "OAT = C?"
240 PROMPT
241 STO 03
242 "IAS = KTS?"
243 PROMPT
244 STO 04
245 "FUEL = LBS?"
246 PROMPT
247 RCL 00
248 +
249 STO 01
250 RTN
251♦LBL C
252 SF 02
253 CF 01
254 CF 03
255 "**MAX ENDUR*"
256 AVIEW
257 PSE
258 XEQ 08
259♦LBL 09
260 54.75
261 RCL 01
262 155 E-5
263 *
264 +
265 STO 13
266 GTO 01
267♦LBL 10
268 XEQ 02
269 RCL 13
270 RCL 07
271 -
272 STO 14
273 RCL 10
274 *
275 STO 11
276 BEEP
277 "*DATA READY*"
278 PROMPT
279 GTO F
280♦LBL D
281 SF 03
282 CF 01
283 CF 02
284 "*MR DESCENT*"
285 AVIEW
286 PSE
287 "ALT = FT?"
288 PROMPT
289 STO 02
290 "FUEL = LBS?"
291 PROMPT
292 RCL 00
293 +
294 STO 01
295 "L/O ALT = ?"
296 PROMPT
297 STO 20
298 RCL 02
299 -
300 CHS
```

E-2B FPAS/HP-41CV Code (June 1982; 3/3)

```
301 RCL 01
302 40000
303 -
304 134367 E-13
305 *
306 1676 E-6
307 +
308 *
309 FIX 0
310 "DSND.DIST="
311 ARCL X
312 PROMPT
313◆LBL 11
314 10000
315 RCL 02
316 X>Y?
317 GTO 12
318 RCL 02
319 -77 E-7
320 *
321 E↑X
322 162.4
323 *
324 XEQ 16
325 GTO 13
326◆LBL 12
327 RCL 02
328 -239 E-8
329 *
330 E↑X
331 153.1
332 *
333 XEQ 16
334◆LBL 13
335 STO 13
336 RCL 12
337 X>0?
338 GTO 06
339 XEQ 07
340◆LBL 14
341 XEQ 02
342 RCL 13
343 RCL 07
344 -
345 STO 14
346 FS? 04
347 GTO 15
348 " ** NOTE **"
349 AVIEW
350 PSE
351 "UPDTE MRD.IAS"
352 AVIEW
353 PSE
354 "EVERY 2000FT"
355 AVIEW
356 PSE
357 "USE 500 SHP"
358 AVIEW
359 PSE
360 SF 04
361◆LBL 15
362 "MRD IAS="
363 ARCL 14
364 PROMPT
365 "NEW ALT = ?"
366 PROMPT
367 STO 02
368 GTO 11
369◆LBL 16
370 RCL 02
371 .9
372 *
373 LN
374 4.57
375 +
376 RCL 01
377 40000
378 -
379 *
380 10000
381 /
382 +
383 RTN
384◆LBL F
385 FIX 0
386 FS? 01
387 GTO 17
388 FC? 01
389 GTO 19
390◆LBL 17
391 "*RCMD MR IAS"
392 AVIEW
393 PSE
394 "*PRESENT ALT"
395 AVIEW
396 PSE
397◆LBL 18
398 "*MR IAS="
399 ARCL 14
400 PROMPT
401 "*MR TAS="
402 ARCL 11
403 PROMPT
404 "*HW = "
405 ARCL 12
406 PROMPT
407 "RCMD CRS CLG"
408 AVIEW
409 PSE
410 "CC = "
411 ARCL 06
412 PROMPT
413 "GW = "
414 ARCL 01
415 PROMPT
416 "UPDATE e 30M"
417 AVIEW
418 PSE
419 GTO 18
420◆LBL 19
421 "+RCMD ME IAS"
422 AVIEW
423 PSE
424 "+PRESENT ALT"
425 AVIEW
426 PSE
427◆LBL 20
428 "+ME IAS="
429 ARCL 14
430 PROMPT
431 "GW = "
432 ARCL 01
433 PROMPT
434 "UPDATE e 30M"
435 AVIEW
436 PSE
437 GTO 20
438◆LBL G
439 CF 00
440 CF 01
441 CF 02
442 CF 03
443 CF 04
444 FIX 4
445 CLX
446 .END.
```

4.1.4 Governing Equations

Register locations for the E-2B FPAS are the same as for the E-2C and will not be repeated. Governing equations, obviously, will be different and are listed here for the record. The headwind corrections used in this program are the same as those in the E-2C program. Equations common to both programs are not listed.

Cruise Ceiling: CC = f(TDEV,GW)

CC = 58550 + 78.67(30-TDEV) -

- (1-0.0031(30-TDEV)) (0.705)(GW)

Max Range Calibrated Airspeed: MRCAS = f(PA,GW)

MRCAS = 174.838 + 75E-5(GW) - 2522E-6(PA)

+ 5580656E-15(GW)(PA) + 671E-15(GW)(PA)**2

Max Endurance Calibrated Airspeed: MECAS = f(GW)

MECAS = 54.75 + 155E-5(GW)

Descent Distance: DD = f(PA,LOPA,GW)

DD = (PA-LOPA)((GW-40000)(13436E-13)+(1676E-6))

Max Range Descent CAS (>10000): MRDCAS = f(PA,GW)

MRDCAS = 153.1exp((PA)(-239E-8))

+ ((4.57 + LN(.9PA))(GW-40000)/10000)

Max Range Descent CAS (<10000): MRDCAS = f(PA,GW)

MRDCAS = 162.4exp((PA)(-77E-7))

+ ((4.57 + LN(.9PA))(GW-40000)/10000)

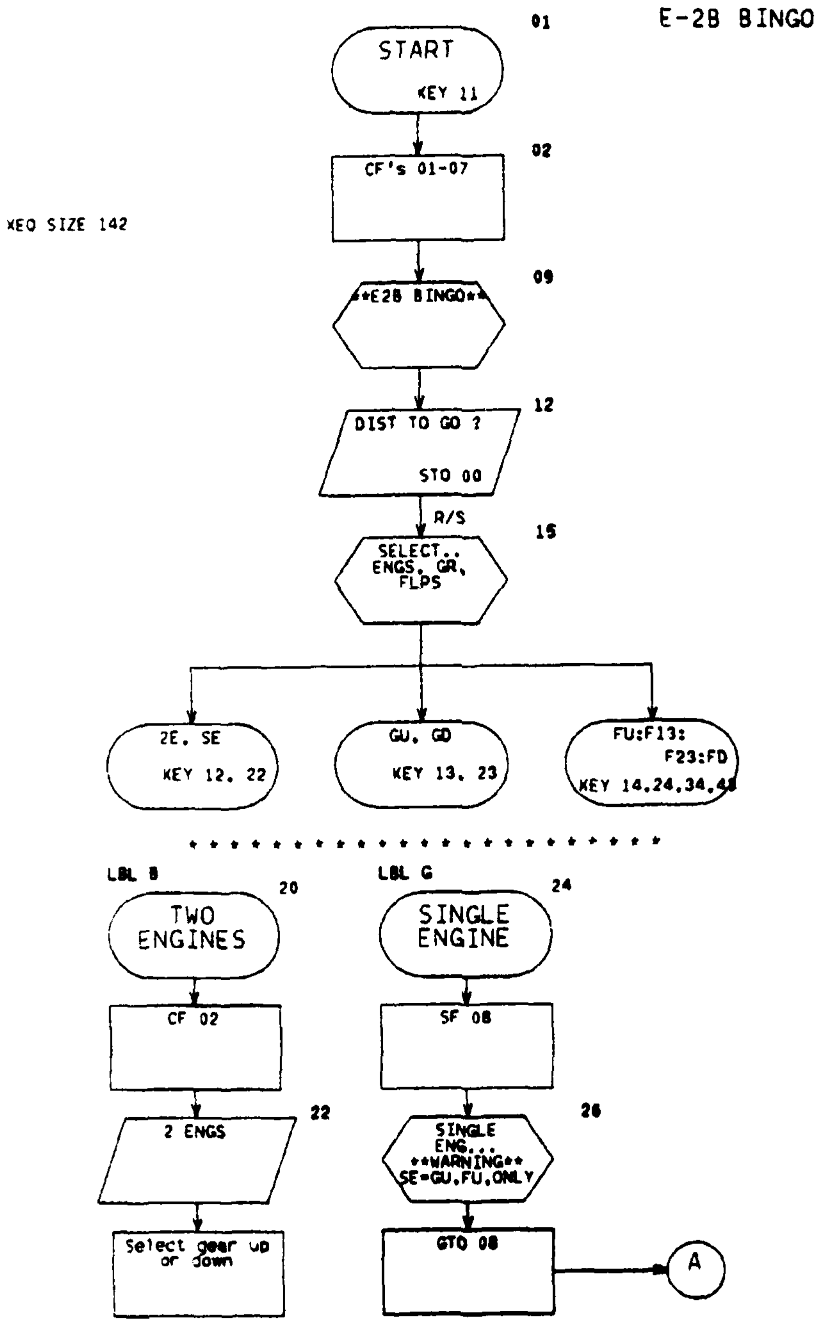
4.2 THE E-2B BINGO PROGRAM

The seven BINGO flight configurations used for the E-2C are used also for the E-2B. Program operation is essentially the same in all respects.

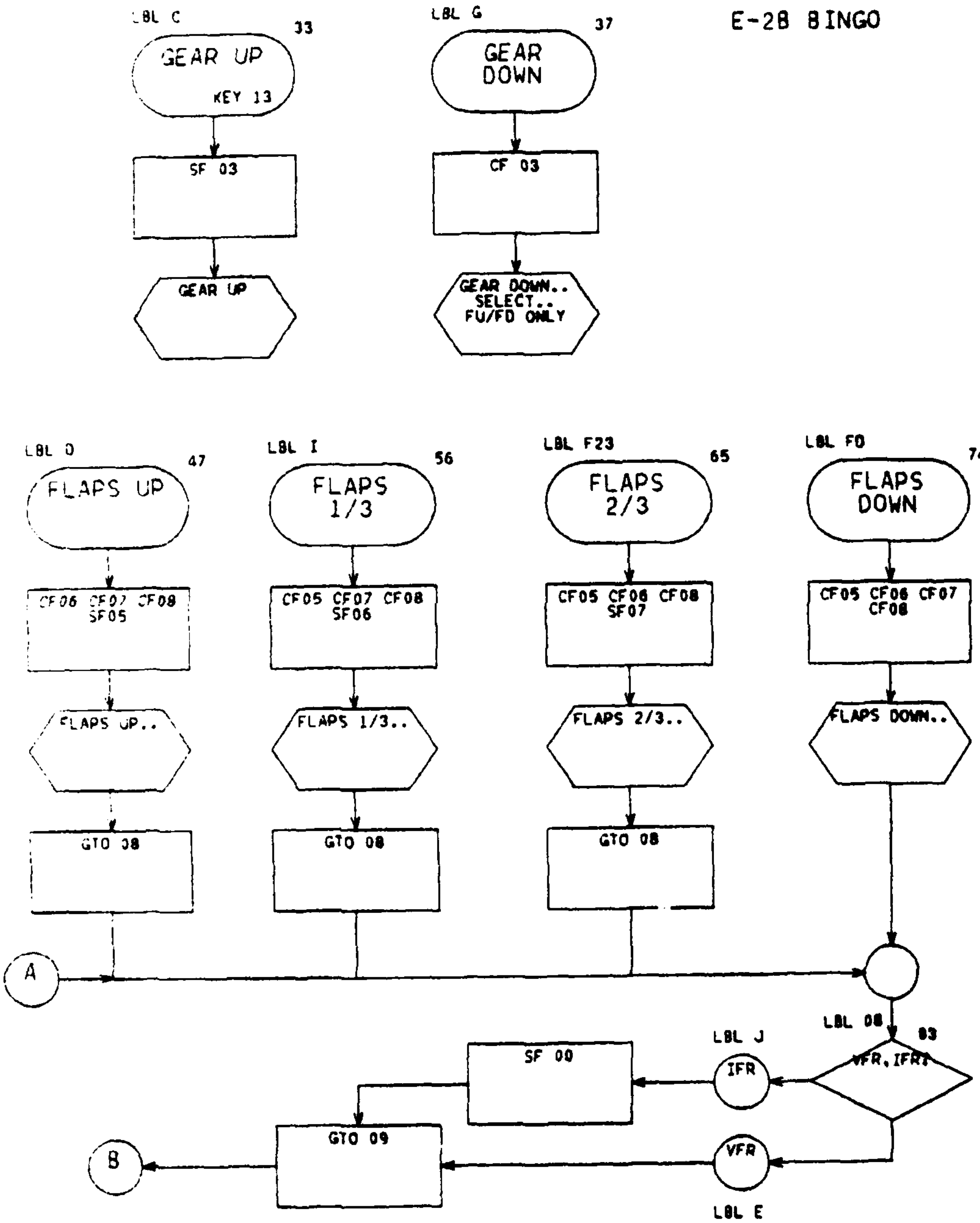
The fuel and time required values used in the data set were chosen by taking the smallest value of fuel required per horizontal line in the chart (primary) and/or the smallest time required (secondary). 900 pounds of fuel is used to add for IFR fuel required.

As in the case of the E-2B FPAS, no significant changes have been made in the E-2B BINGO charts in spite of engine modifications and a propeller system change. It is requested that any "gouge" figures used by E-2B squadrons to modify these numbers be brought to the attention of the author so that appropriate software changes can be made.

The following pages show flowcharts and program code for the E-2B BINGO program.


E-2B BINGO
01
START
KEY 11
02
CF's 01-07
XEQ SIZE 142
09
E2B BINGO
12
DIST TO GO ?
STO 00
R/S
15
SELECT..
ENGS, GR,
FLPS
2E, SE
KEY 12, 22
GU, GD
KEY 13, 23
FU:F13:
F23:FD
KEY 14,24,34,44
LBL B
20
TWO
ENGINES
LBL G
24
SINGLE
ENGINE
CF 02
SF 08
22
2 ENGS
26
SINGLE
ENG...
WARNING
SE=GU,FU,ONLY
Select gear up
or down
GTO 08
A

1/7

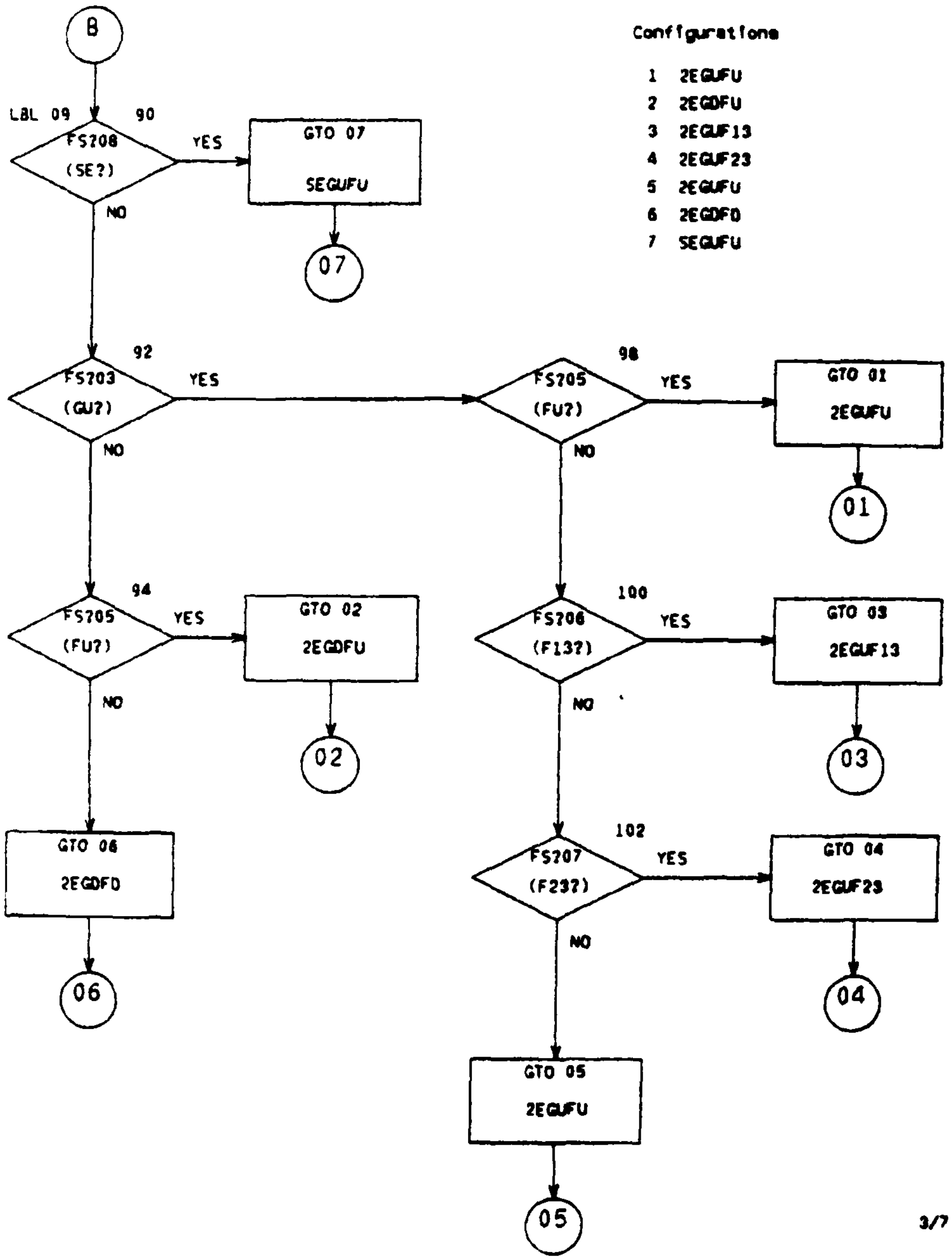

E-2B BINGO
LBL C
33
GEAR UP
KEY 13
SF 03
GEAR UP
LBL G
37
GEAR DOWN
CF 03
GEAR DOWN..
SELECT..
FU/FD ONLY
LBL D
47
FLAPS UP
CF06 CF07 CF08
SF05
FLAPS UP..
GTO 08
LBL I
56
FLAPS 1/3
CF05 CF07 CF08
SF06
FLAPS 1/3..
GTO 08
LBL F23
65
FLAPS 2/3
CF05 CF06 CF08
SF07
FLAPS 2/3..
GTO 08
LBL FD
74
FLAPS DOWN
CF05 CF06 CF07
CF08
FLAPS DOWN..
A
LBL 08
83
VFR, IFR?
LBL J
IFR
SF 00
GTO 09
B
VFR
LBL E

2/7

E-2B BINGO

Configurations

1 2EGUFU
2 2EGDFU
3 2EGUF13
4 2EGUF23
5 2EGUFU
6 2EGDFD
7 SEGUFU



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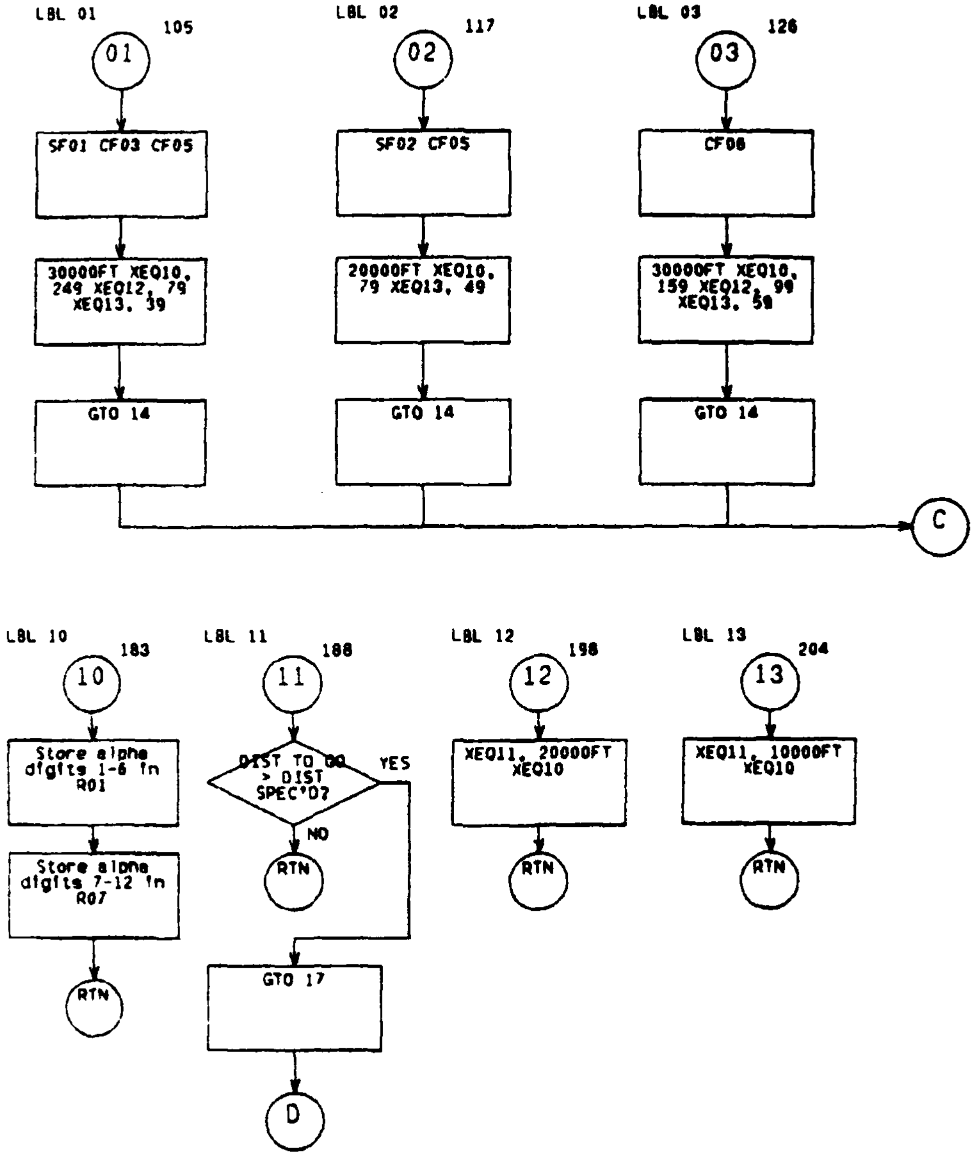
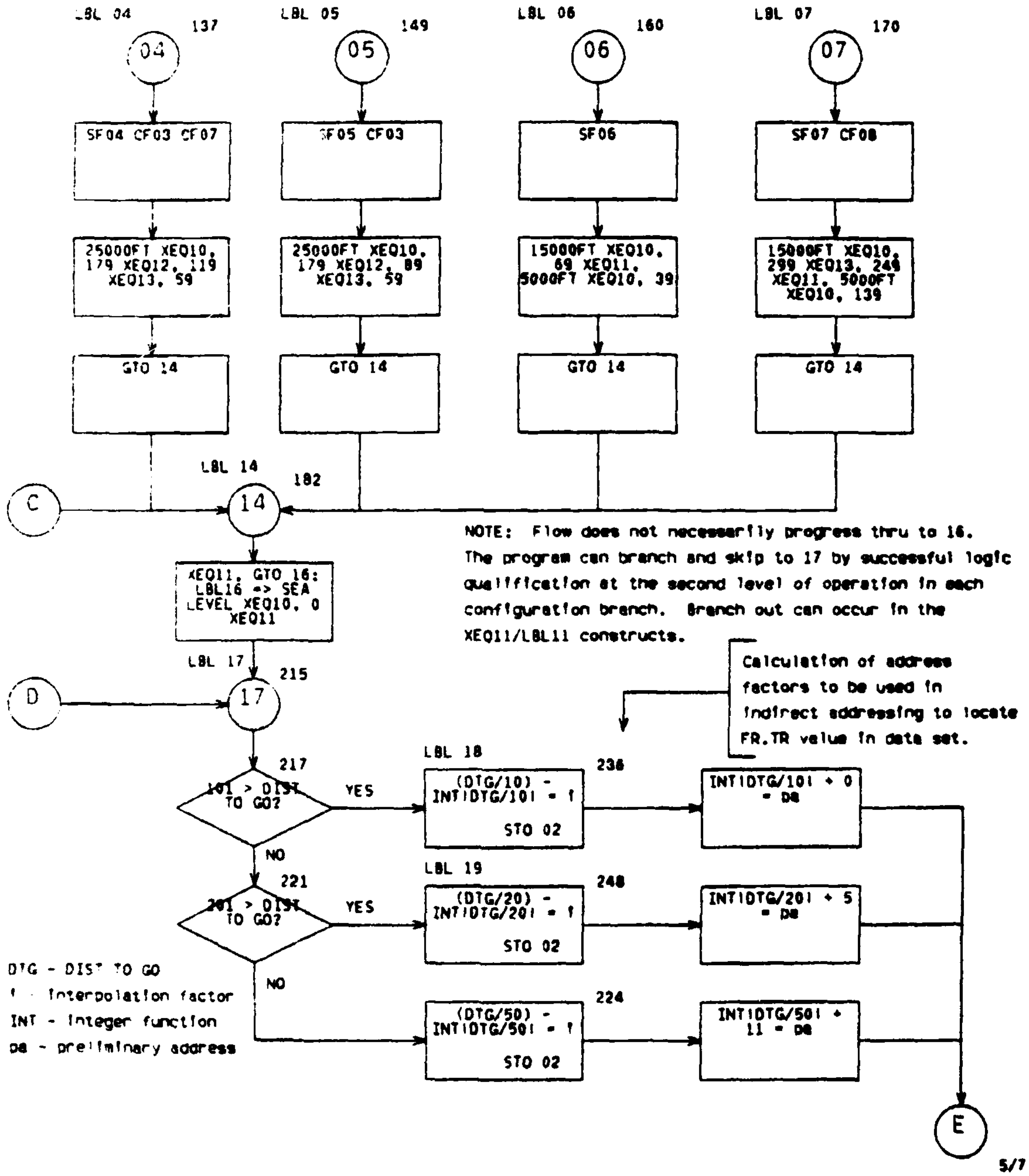
E-2B BINGO



LBL 01
105
01
SF01 CF03 CF05
30000FT XEQ10, 249 XEQ12, 79 XEQ13, 39
GTO 14
LBL 02
117
02
SF02 CF05
20000FT XEQ10, 79 XEQ13, 49
GTO 14
LBL 03
126
03
CF06
30000FT XEQ10, 159 XEQ12, 99 XEQ13, 59
GTO 14
C
LBL 10
183
10
Store alpha digits 1-6 in R01
Store alpha digits 7-12 in R07
RTN
LBL 11
188
11
DIST TO GO > DIST SPEC'D?
YES
NO
RTN
GTO 17
D
LBL 12
198
12
XEQ11, 20000FT XEQ10
RTN
LBL 13
204
13
XEQ11, 10000FT XEQ10
RTN

E-2B BINGO


LBL 04
137
04
SF04 CF03 CF07
25000FT XEQ10, 179 XEQ12, 119 XEQ13, 59
GTO 14
LBL 05
149
05
SF05 CF03
25000FT XEQ10, 179 XEQ12, 89 XEQ13, 59
GTO 14
LBL 06
160
06
SF06
15000FT XEQ10, 69 XEQ11, 5000FT XEQ10, 39
GTO 14
LBL 07
170
07
SF07 CF08
15000FT XEQ10, 299 XEQ13, 249 XEQ11, 5000FT XEQ10, 139
GTO 14
C
LBL 14
182
14
NOTE: Flow does not necessarily progress thru to 16. The program can branch and skip to 17 by successful logic qualification at the second level of operation in each configuration branch. Branch out can occur in the XEQ11/LBL11 constructs.
XEQ11, GTO 16: LBL16 => SEA LEVEL XEQ10, 0 XEQ11
LBL 17
215
D
17
Calculation of address factors to be used in indirect addressing to locate FR.TR value in data set.
217
101 > DIST TO GO?
YES
LBL 18
236
(DTG/10) - INT(DTG/10) = f
STO 02
INT(DTG/10) + 0 = pa
NO
221
201 > DIST TO GO?
YES
LBL 19
248
(DTG/20) - INT(DTG/20) = f
STO 02
INT(DTG/20) + 5 = pa
NO
224
(DTG/50) - INT(DTG/50) = f
STO 02
INT(DTG/50) + 11 = pa
DTG - DIST TO GO
f - interpolation factor
INT - integer function
pa - preliminary address
E

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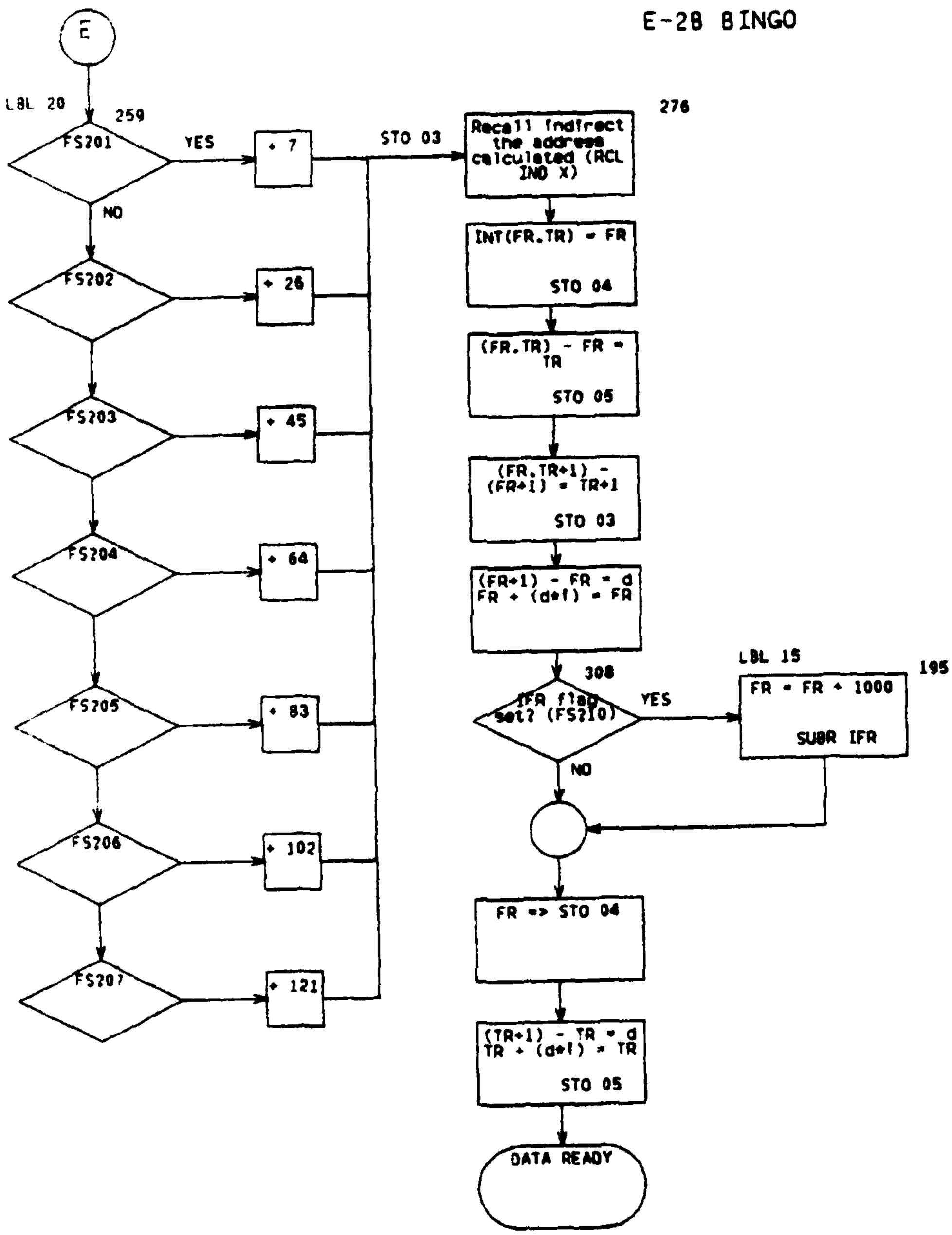
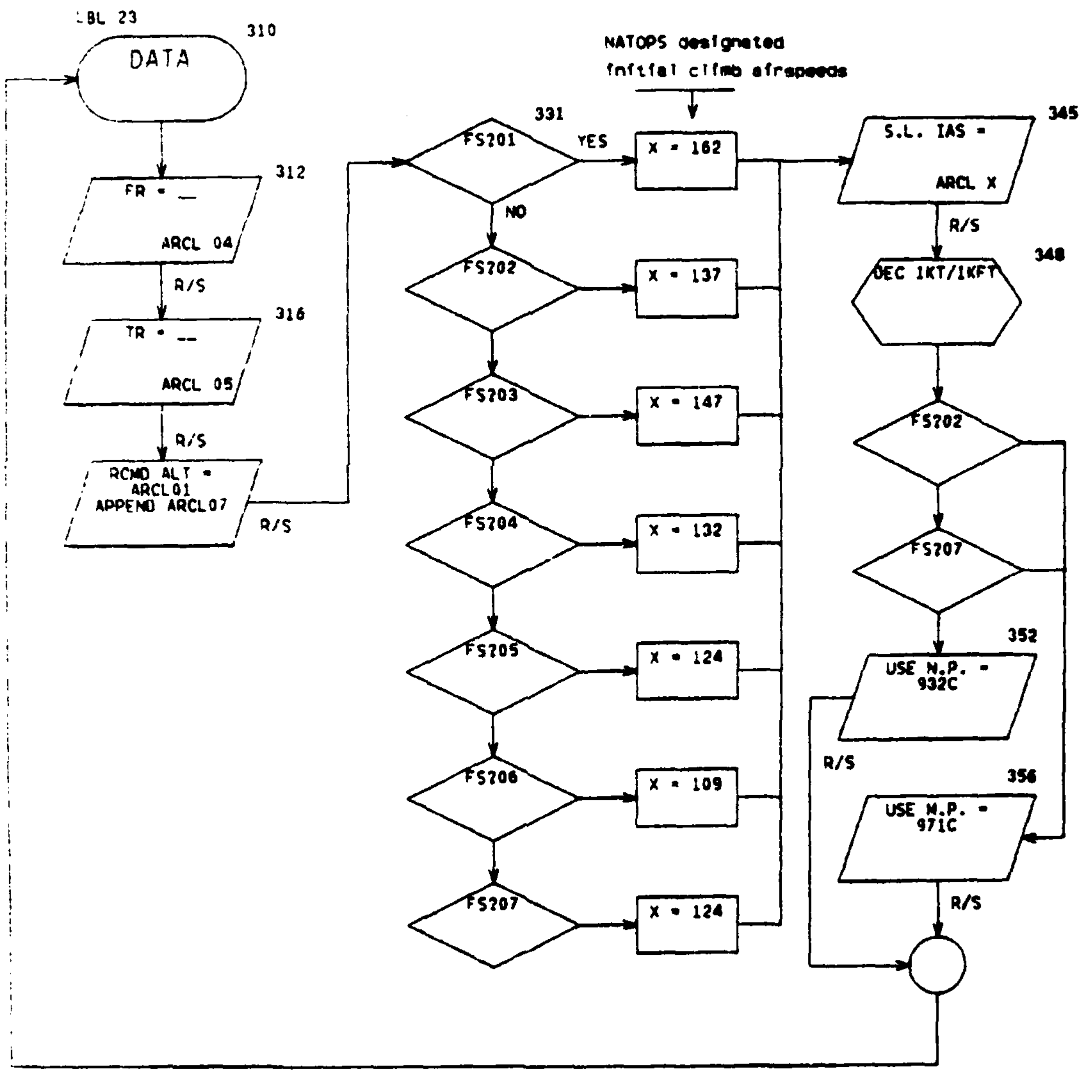

E
E-2B BINGO
LBL 20
259
FS?01
YES
NO
+ 7
STO 03
276
Recall indirect the address calculated (RCL IND X)
FS?02
+ 26
INT(FR.TR) = FR
STO 04
FS?03
+ 45
(FR.TR) - FR = TR
STO 05
(FR.TR+1) - (FR+1) = TR+1
STO 03
FS?04
+ 64
(FR+1) - FR = d
FR + (d*f) = FR
FS?05
+ 83
LBL 15
195
308
IFR flag set? (FS?10)
YES
FR = FR + 1000
SUBR IFR
NO
FS?06
+ 102
FS?07
+ 121
FR => STO 04
(TR+1) - TR = d
TR + (d*f) = TR
STO 05
DATA READY

E-2B BINGO


LBL 23
310
DATA
312
FR = __
ARCL 04
R/S
316
TR = __
ARCL 05
R/S
RCMD ALT =
ARCL 01
APPEND ARCL 07
R/S
NATOPS designated
initial climb airspeeds
331
FS?01
YES
NO
X = 162
FS?02
X = 137
FS?03
X = 147
FS?04
X = 132
FS?05
X = 124
FS?06
X = 109
FS?07
X = 124
345
S.L. IAS =
ARCL X
R/S
348
DEC 1KT/1KFT
FS?02
FS?07
352
USE N.P. =
932C
R/S
356
USE N.P. =
971C
R/S

E-2B BINGO/HP-41CV Code (June 1982; 1/4)

```
01♦LBL "STB"
02 CF 01
03 CF 02
04 CF 03
05 CF 04
06 CF 05
07 CF 06
08 CF 07
09 "**E2B BINGO*"
10 AVIEW
11 PSE
12 "DIST TO GO ?"
13 PROMPT
14 STO 00
15 "SELECT.."
16 AVIEW
17 PSE
18 "ENGS, GR, FLPS"
19 PROMPT
20♦LBL B
21 CF 02
22 "2 ENGS"
23 PROMPT
24♦LBL G
25 SF 00
26 "SINGLE ENG..."
27 AVIEW
28 PSE
29 "SE=GU,FU,ONLY.."
30 AVIEW
31 PSE
32 GTO 08
33♦LBL C
34 SF 03
35 "GEAR UP"
36 PROMPT
37♦LBL H
38 CF 03
39 "GEAR DOWN.."
40 AVIEW
41 PSE
42 "SELECT.."
43 AVIEW
44 PSE
45 "FU/FD ONLY"
46 PROMPT
47♦LBL D
48 CF 06
49 CF 07
50 CF 08
51 SF 05
52 "FLAPS UP.."
53 AVIEW
54 PSE
55 GTO 08
56♦LBL I
57 CF 05
58 CF 07
59 CF 08
60 SF 06
61 "FLAPS 1/3.."
62 AVIEW
63 PSE
64 GTO 08
65♦LBL "F23"
66 CF 05
67 CF 06
68 CF 08
69 SF 07
70 "FLAPS 2/3.."
71 AVIEW
72 PSE
73 GTO 08
74♦LBL "FD"
75 CF 05
76 CF 06
77 CF 07
78 CF 08
79 "FLAPS DOWN..."
80 AVIEW
81 PSE
82♦LBL 08
83 " VFR, IFR ?"
84 PROMPT
85♦LBL E
86 GTO 09
87♦LBL J
88 SF 10
89♦LBL 09
90 FS? 00
91 GTO 07
92 FS? 03
93 GTO 22
94 FS? 05
95 GTO 02
96 GTO 06
97♦LBL 22
98 FS? 05
99 GTO 01
100 FS? 06
101 GTO 03
102 FS? 07
103 GTO 04
104 GTO 05
105♦LBL 01
106 SF 01
107 CF 03
108 CF 05
109 "30000 FT"
110 XEQ 10
111 249
112 XEQ 12
113 79
114 XEQ 13
115 39
116 GTO 14
117♦LBL 02
118 CF 05
119 SF 02
120 "20000 FT"
121 XEQ 10
122 79
123 XEQ 13
124 49
125 GTO 14
126♦LBL 03
127 SF 03
128 CF 06
129 "30000 FT"
130 XEQ 10
131 159
132 XEQ 12
133 99
134 XEQ 13
135 59
136 GTO 14
137♦LBL 04
138 CF 07
139 CF 03
140 SF 04
141 "25000 FT"
142 XEQ 10
143 179
144 XEQ 12
145 119
146 XEQ 13
147 59
148 GTO 14
149♦LBL 05
150 CF 03
```

E-2B BINGO/HP-41CV Code (June 1982; 2/4)

```
151 SF 05
152 "25000 FT"
153 XEQ 10
154 179
155 XEQ 12
156 89
157 XEQ 13
158 59
159 GTO 14
160+LBL 06
161 SF 06
162 "15000 FT"
163 XEQ 10
164 69
165 XEQ 11
166 " 5000 FT"
167 XEQ 10
168 39
169 GTO 14
170+LBL 07
171 CF 08
172 SF 07
173 "15000 FT"
174 XEQ 10
175 299
176 XEQ 13
177 249
178 XEQ 11
179 " 5000 FT"
180 XEQ 10
181 139
182+LBL 14
183 XEQ 11
184 GTO 16
185+LBL 10
186 ASTO 01
187 ASHF
188 ASTO 07
189 RTN
190+LBL 11
191 RCL 00
192 X>Y?
193 GTO 17
194 RTN
195+LBL 15
196 CF 10
197 900
198 +
199 RTN
200+LBL 12
201 XEQ 11
202 "20000 FT"
203 XEQ 10
204 RTN
205+LBL 13
206 XEQ 11
207 "10000 FT"
208 XEQ 10
209 RTN
210+LBL 16
211 " SEA LEVEL"
212 XEQ 10
213 0
214 XEQ 11
215+LBL 17
216 RCL 00
217 101
218 X>Y?
219 GTO 18
220 X<>Y
221 201
222 X>Y?
223 GTO 19
224 RCL 00
225 50
226 /
227 ENTER↑
228 INT
229 STO 03
230 -
231 STO 02
232 RCL 03
233 11
234 GTO 20
235+LBL 18
236 RCL 00
237 10
238 /
239 ENTER↑
240 INT
241 STO 03
242 -
243 STO 02
244 RCL 03
245 0
246 GTO 20
247+LBL 19
248 RCL 00
249 20
250 /
251 ENTER↑
252 INT
253 STO 03
254 -
255 STO 02
256 RCL 03
257 5
258+LBL 20
259 +
260 FS? 01
261 7
262 FS? 02
263 26
264 FS? 03
265 45
266 FS? 04
267 64
268 FS? 05
269 83
270 FS? 06
271 102
272 FS? 07
273 121
274 +
275 STO 03
276 RCL IND X
277 ENTER↑
278 INT
279 STO 04
280 -
281 STO 05
282 1
283 ST+ 03
284 RCL IND 03
285 ENTER↑
286 INT
287 STO 06
288 -
289 STO 03
290 RCL 06
291 RCL 04
292 -
293 RCL 02
294 *
295 RCL 04
296 +
297 FS? 10
298 XEQ 15
299 STO 04
300 RCL 03
```

E-2B BINGO/HP-41CV Code (June 1982; 3/4)

```
301 RCL 05
302 -
303 RCL 02
304 *
305 RCL 05
306 +
307 10
308 *
309 STO 05
310•LBL 21
311•LBL 23
312 FIX 0
313 " FR = "
314 ARCL 04
315 FIX 2
316 PROMPT
317 " TR = "
318 ARCL 05
319 PROMPT
320 "RCMMD ALT = "
321 AVIEW
322 PSE
323 CLA
324 ARCL 01
325 "├"
326 ARCL 07
327 PROMPT
328 FIX 0
329 " DIST = "
330 ARCL 00
331 PROMPT
332 FS? 01
333 162
334 FS? 02
335 137
336 FS? 03
337 147
338 FS? 04
339 132
340 FS? 05
341 124
342 FS? 06
343 109
344 FS? 07
345 124
346 "S.L. IAS = "
347 ARCL X
348 PROMPT
349 "DEC 1KT/1KFT"
350 PROMPT
351 FS? 07
352 GTO 38
353 "USE N.P.= 932C"
354 PROMPT
355 GTO 23
356•LBL 38
357 "USE N.P.= 971C"
358 PROMPT
359 GTO 23
360 .END.
```

```
R00=  0.000
R01=  1.000
R02=  2.000
R03=  3.000
R04=  4.000
R05=  5.000
R06=  6.000
R07=  7.000
R08=  1,220.003
R09=  1,320.006
R10=  1,440.009
R11=  1,520.012
R12=  1,610.014
R13=  1,700.017
R14=  1,790.020
R15=  1,850.022
R16=  1,930.025
R17=  2,000.028
R18=  2,150.033
R19=  2,290.038
R20=  2,440.043
R21=  2,530.048
R22=  2,730.053
R23=  3,090.101
R24=  3,390.112
R25=  3,700.123
R26=  4,000.135
R27=  1,240.004
R28=  1,390.007
R29=  1,530.011
R30=  1,680.014
R31=  1,800.018
R32=  1,920.021
R33=  2,040.024
R34=  2,160.026
R35=  2,250.029
R36=  2,350.032
R37=  2,540.038
R38=  2,740.044
R39=  2,930.050
R40=  3,130.056
R41=  3,320.102
R42=  3,810.117
R43=  4,290.132
R44=  4,780.147
R45=  5,270.202
R46=  1,220.003
R47=  1,340.006
R48=  1,470.009
R49=  1,590.012
R50=  1,710.015
R51=  1,800.019
R52=  1,900.022
R53=  2,000.024
R54=  2,090.027
R55=  2,170.030
R56=  2,330.035
R57=  2,490.040
R58=  2,630.044
R59=  2,770.049
R60=  2,900.054
R61=  3,240.105
R62=  3,580.117
R63=  3,920.129
R64=  4,260.141
R65=  1,240.003
R66=  1,380.007
R67=  1,520.011
R68=  1,660.014
R69=  1,800.018
R70=  1,910.022
R71=  2,020.025
R72=  2,130.028
R73=  2,240.032
R74=  2,350.035
R75=  2,520.041
R76=  2,700.048
R77=  2,880.054
R78=  3,050.100
R79=  3,210.106
R80=  3,620.120
R81=  4,020.135
R82=  4,430.150
R83=  4,830.205
R84=  1,260.004
R85=  1,430.008
```

E-2B BINGO/HP-41CV Code (June 1982; 4/4)

R86= 1,600.011
R87= 1,750.015
R88= 1,920.019
R89= 2,060.023
R90= 2,200.026
R91= 2,330.030
R92= 2,460.032
R93= 2,570.035
R94= 3,000.042
R95= 3,030.048
R96= 3,260.055
R97= 3,190.101
R98= 3,700.107
R99= 4,250.122
R100= 4,780.137
R101= 5,330.152
R102= 9,999.999
R103= 1,290.004
R104= 1,470.008
R105= 1,650.013
R106= 1,840.017
R107= 2,010.021
R108= 2,170.025
R109= 2,320.029
R110= 2,460.032
R111= 2,630.036
R112= 2,740.040
R113= 3,020.047
R114= 3,290.055
R115= 3,570.103
R116= 3,840.110
R117= 4,120.117
R118= 4,810.136
R119= 5,500.155
R120= 9,[illegible]99.999
R121= 9,999.999
R122= 1,190.004
R123= 1,280.007
R124= 1,360.010
R125= 1,450.014
R126= 1,540.017
R127= 1,620.021
R128= 1,710.024
R129= 1,800.027
R130= 1,880.031
R131= 1,970.034
R132= 2,140.041
R133= 2,300.047
R134= 2,460.054
R135= 2,620.101
R136= 2,780.107
R137= 3,150.123
R138= 3,520.137
R139= 3,870.152
R140= 4,270.207

4.3 THE E-2B CROSSWIND LANDING LIMITATIONS PROGRAM

See the explanation, flowchart and code for the E-2C program.

4.4 SAMPLE PROGRAM OPERATION

Rather than repeat the scenario improvised for the E-2C, a set of program runs are listed here that the user may use to verify program operation.

4.4.1 FPAS

Prompt	Response	
	START	KEY 11
E2B FPAS		
BASIC WT = ?	36000	R/S
CARGO WT = ?	50	R/S
NO. CREW = ?	5	R/S
PROFILE?	RANGE	
**MAX RANGE*		
ALT = FT?	25000	R/S
OAT = C?	-15	R/S
IAS = KTS?	165	R/S
FUEL = LBS?	9500	R/S
GS,AVAIL? Y/N	YES	
GS = KTS?	250	R/S
DATA READY		R/S or KEY 21
*RCMD MR IAS		
*PRESENT ALT		
*MR IAS= 172		R/S
*MR TAS= 271		R/S
*HW = 9		R/S
RCMD CRS CLG		
CC = 27600		R/S
GW = 46550		R/S
UPDATE @ 30M		R/S to repeat data

	ENDUR	KEY 13
**MAX ENDUR*		
ALT = FT?	25000	R/S
OAT = C?	-15	R/S
IAS = KTS?	150	R/S
FUEL = LBS?	6000	R/S
DATA READY		R/S or KEY 21
+RCMD ME IAS		
+PRESENT ALT		
+ME IAS = 121		R/S
GW = 43050		R/S
UPDATE @ 30M		R/S to repeat data

	DESCENT	KEY 14
MR DESCENT		
ALT = FT?	25000	R/S
FUEL = LBS?	4000	R/S
L/O ALT = ?	2000	R/S
DSND,DIST=39		R/S
** NOTE **		
UPDTE MRD,IAS		
EVERY 2000FT		
USE 500 SHP		
MRD IAS = 146		R/S
NEW ALT = ?	23000	R/S
MRD IAS = 148		R/S etc.

4.4.2 BINGO

Prompt	Response	
	START	KEY 11
**E2B BINGO*		
DIST TO GO ?	95	R/S
SELECT..		
ENGS, GR, FLPS	2E	
2 ENGS	GU	
GEAR UP	F13	
FLAPS 1/3..		

VFR, IFR?	VFR	KEY 15
FR = 3030		R/S
TR = 0.29		R/S
RCMND ALT =		
10000 FT		R/S
DIST = 95		R/S
S.L. IAS = 147		R/S
DEC 1KT/1KFT		R/S
USE N.P.= 932C		R/S to repeat data

4.4.3 Crosswind Landing

Refer to section describing program operation for the E-2C.

Chapter V

THE C-2A/HP-41CV PROGRAMS

As in the case of the E-2B, programs for the C-2A were modeled after the E-2C.

5.1 THE C-2A FPAS PROGRAM

Program initiation and "button-ology" are similar to that for the other two aircraft. The DESCENT profile for the C-2A is similar to that for the E-2B. An equation for cruise ceiling[15] could not be devised from information available in the NATOPS.[16] The Sample Program Operation section gives an example of typical responses.

The following pages are the flowcharts for the C-2A FPAS and are notated to correspond to the HP-41CV code that follows.

---

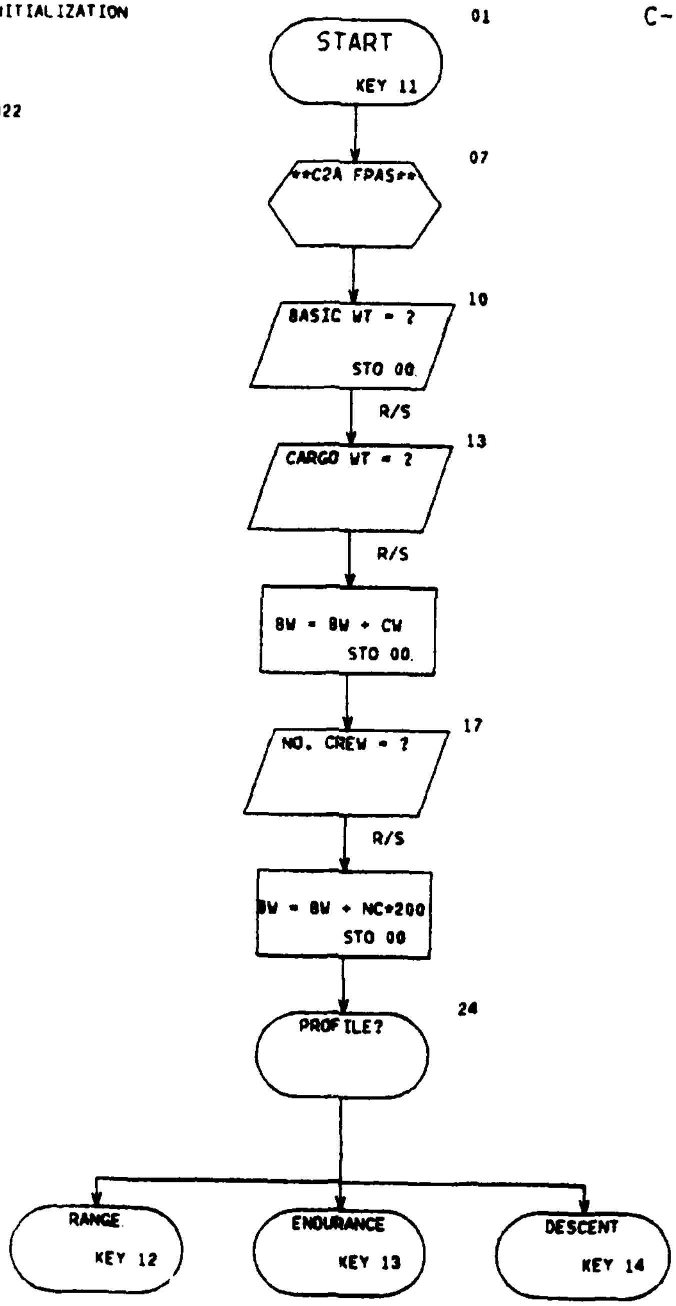
[15] Interestingly enough, one may obtain the service ceiling for the C-2A although this parameter has little utility to fleet operators. A method of obtaining cruise ceiling, the optimal altitude to fly max range, would seem to be more important for an aircraft that can regularly use max range profiles.

[16] Users of this program are advised that, like the E-2B NATOPS, few corrections have been made to Chapter 11 in spite of major changes to the aircraft. If these programs do not conform to actual performance, the program methodology should at least provide a format for future modifications.

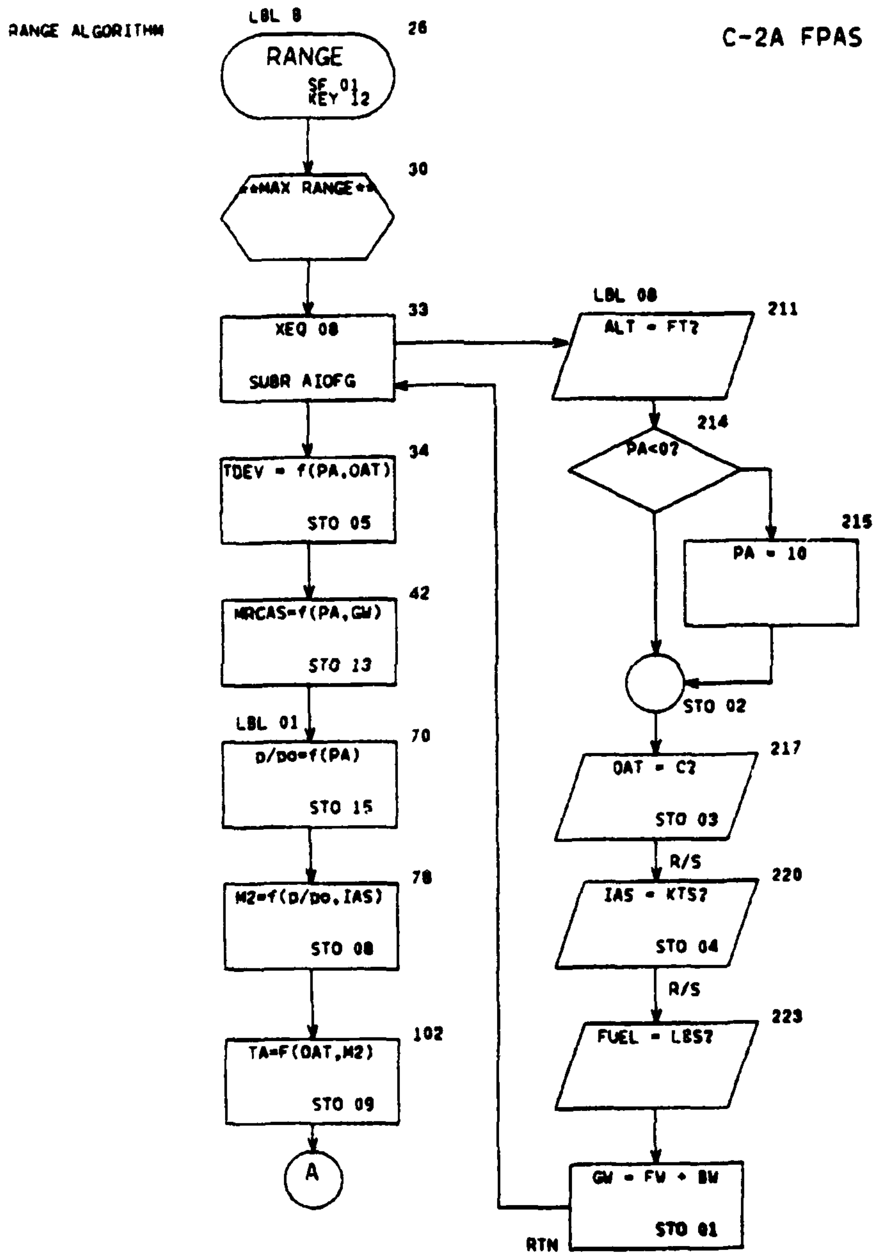
PROGRAM INITIALIZATION

C-2A FPAS

XEQ SIZE 022



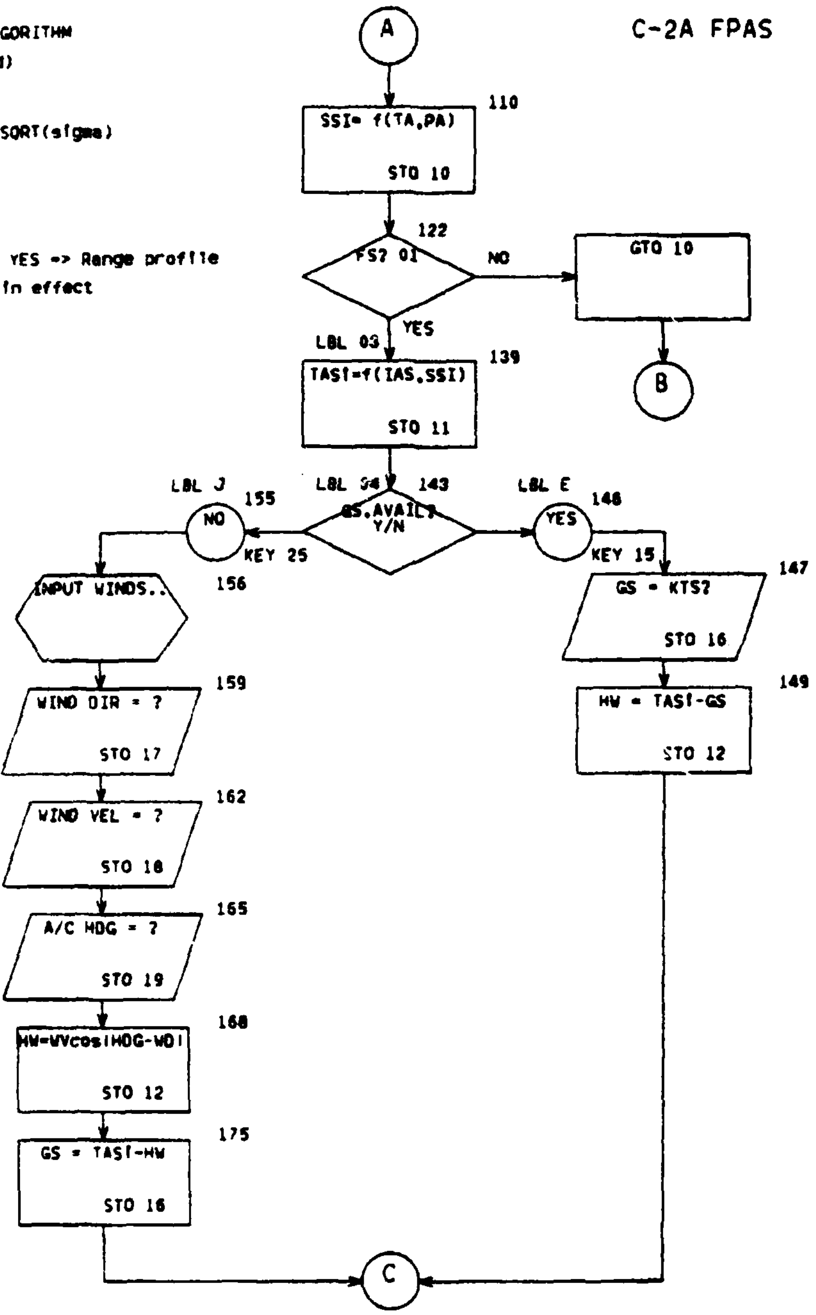
1/9


RANGE ALGORITHM
LBL B
26
RANGE
SF 01
KEY 12
C-2A FPAS
30
MAX RANGE
33
XEQ 08
SUBR AIOFG
LBL 08
211
ALT = FT?
214
PA<0?
215
PA = 10
STO 02
34
TDEV = f(PA,OAT)
STO 05
42
MRCAS=f(PA,GW)
STO 13
LBL 01
70
p/po=f(PA)
STO 15
78
M2=f(p/po,IAS)
STO 08
102
TA=F(OAT,M2)
STO 09
A
217
OAT = C?
STO 03
R/S
220
IAS = KTS?
STO 04
R/S
223
FUEL = LBS?
GW = FW + BW
STO 01
RTN

RANGE ALGORITHM
(cont'd)

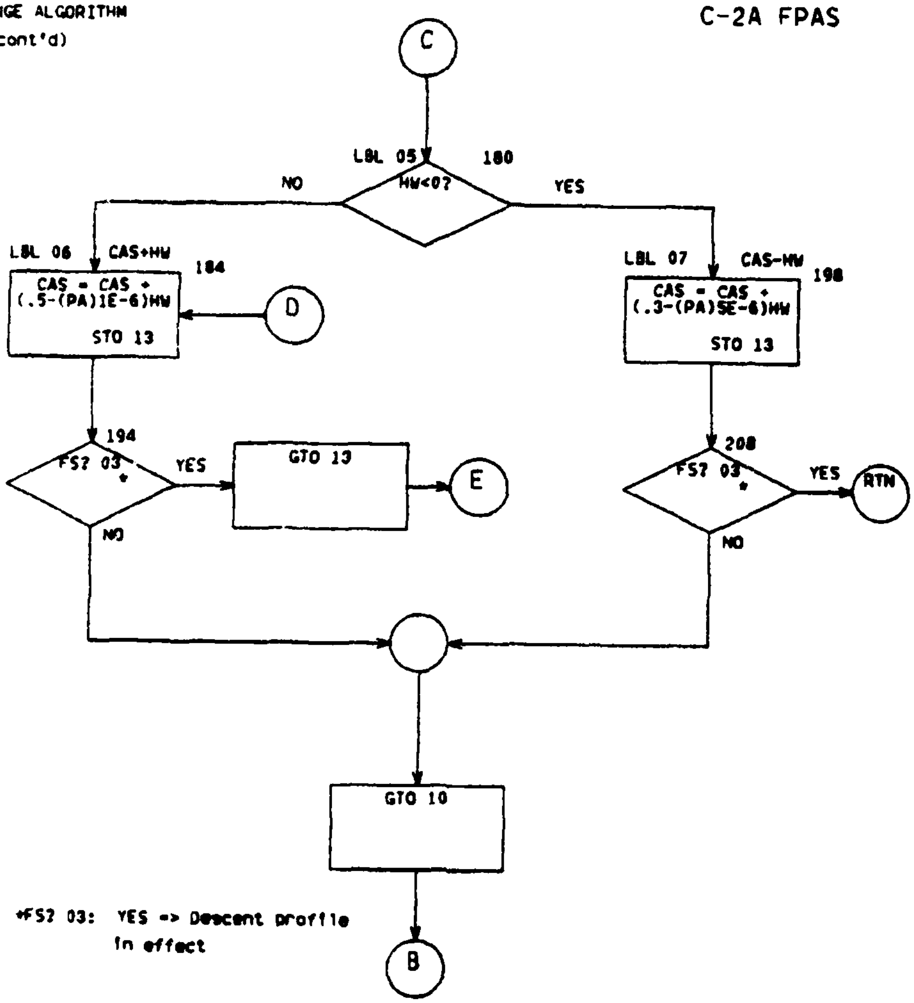
SSI = 1/SQRT(sigma)

FS? 01: YES => Range profile in effect



RANGE ALGORITHM
(cont'd)

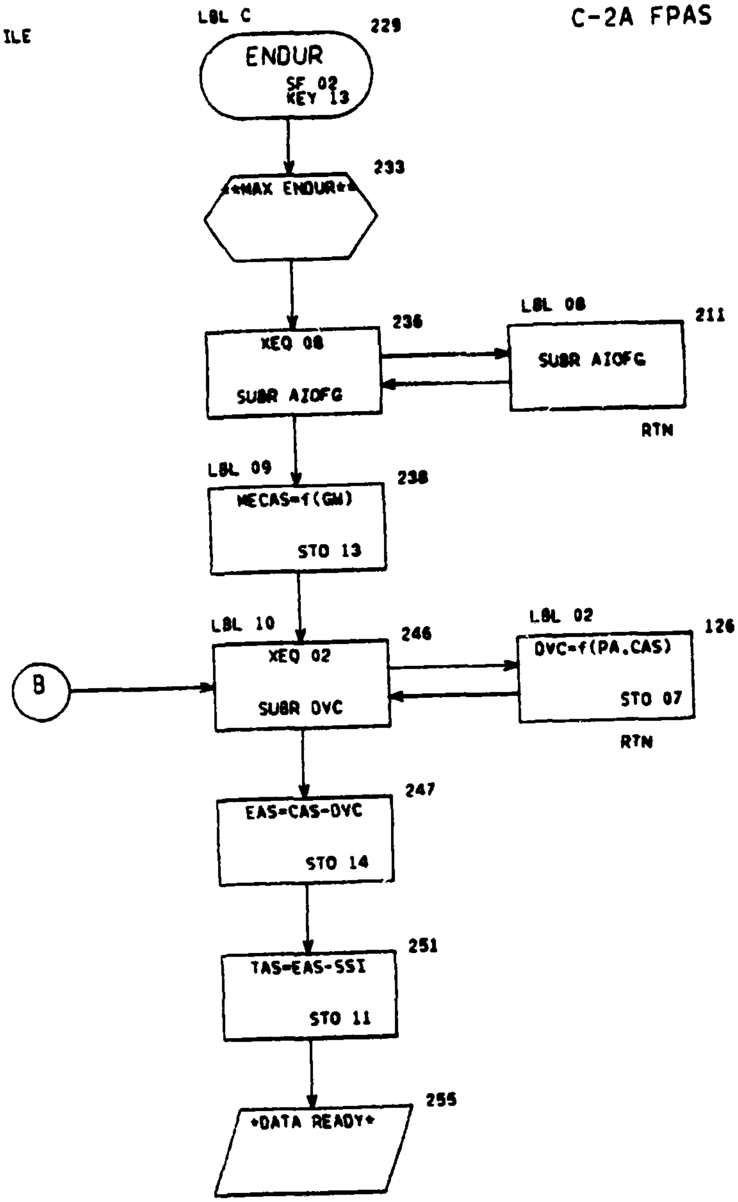
C-2A FPAS



*FS? 03: YES => Descent profile in effect

ENDURANCE PROFILE

C-2A FPAS

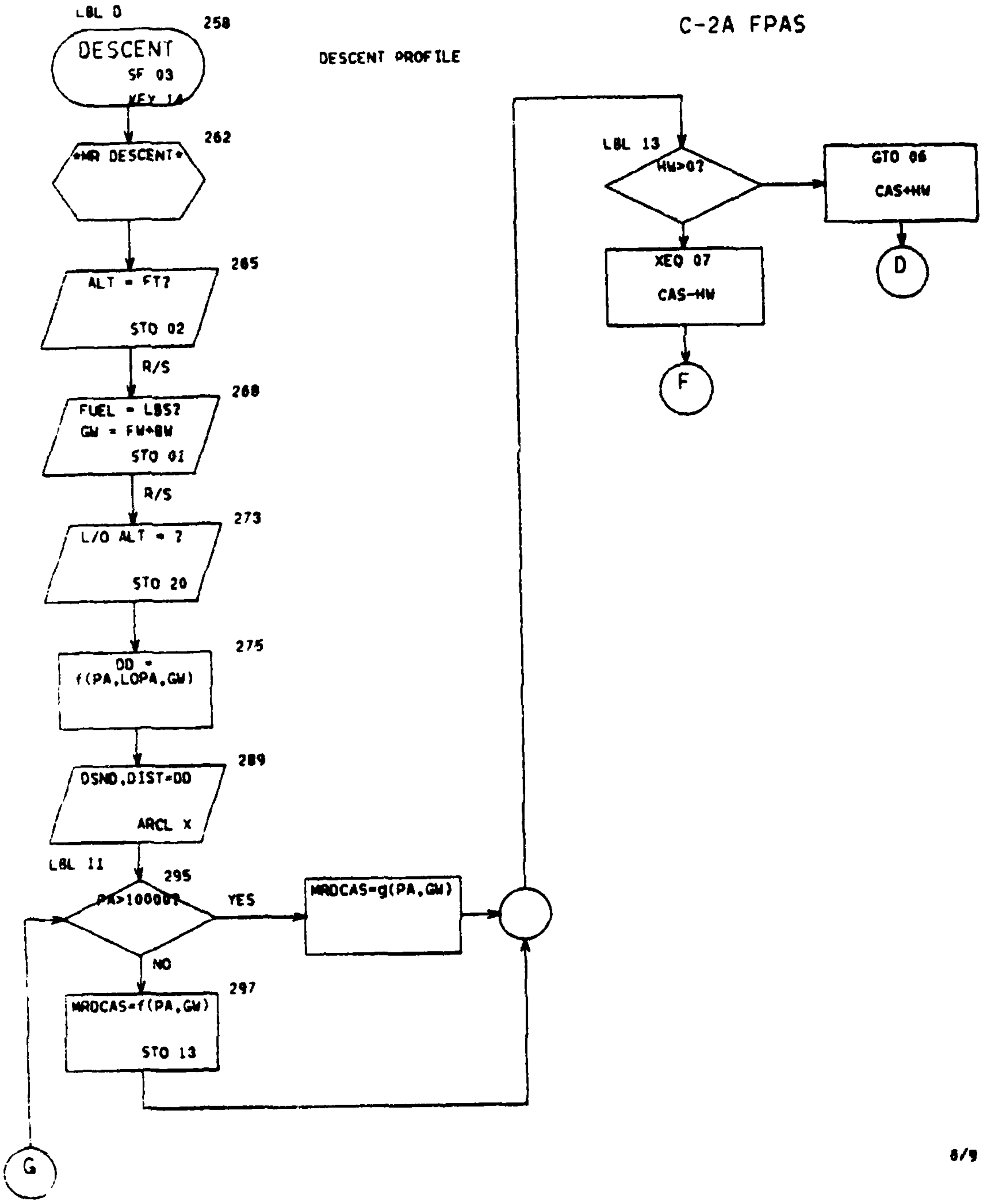


PRESS DATA KEY (21) OR R/S
TO CONTINUE

5/9

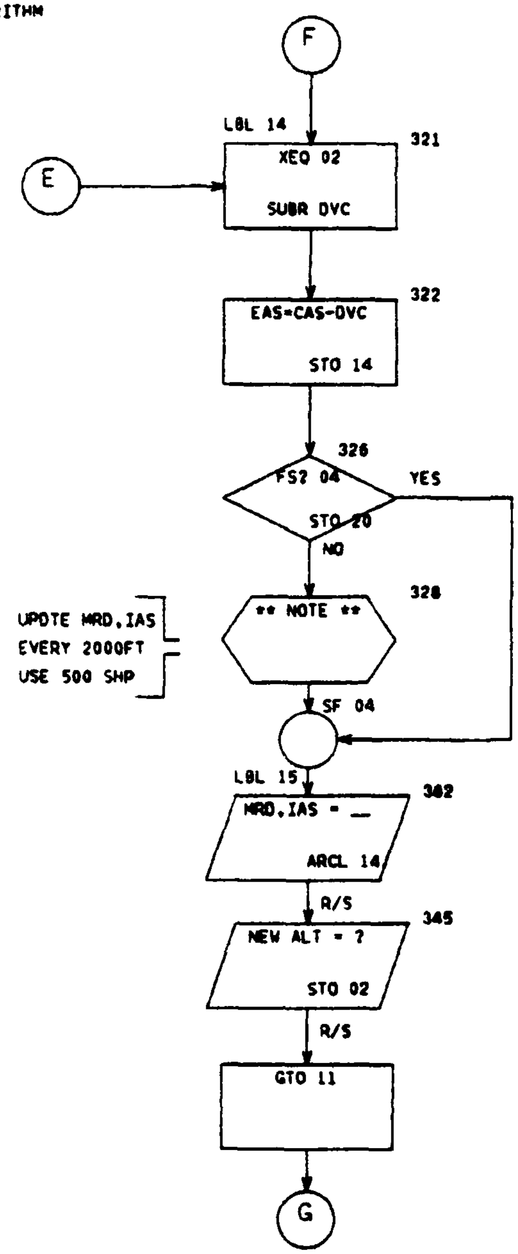
C-2A FPAS

DESCENT PROFILE



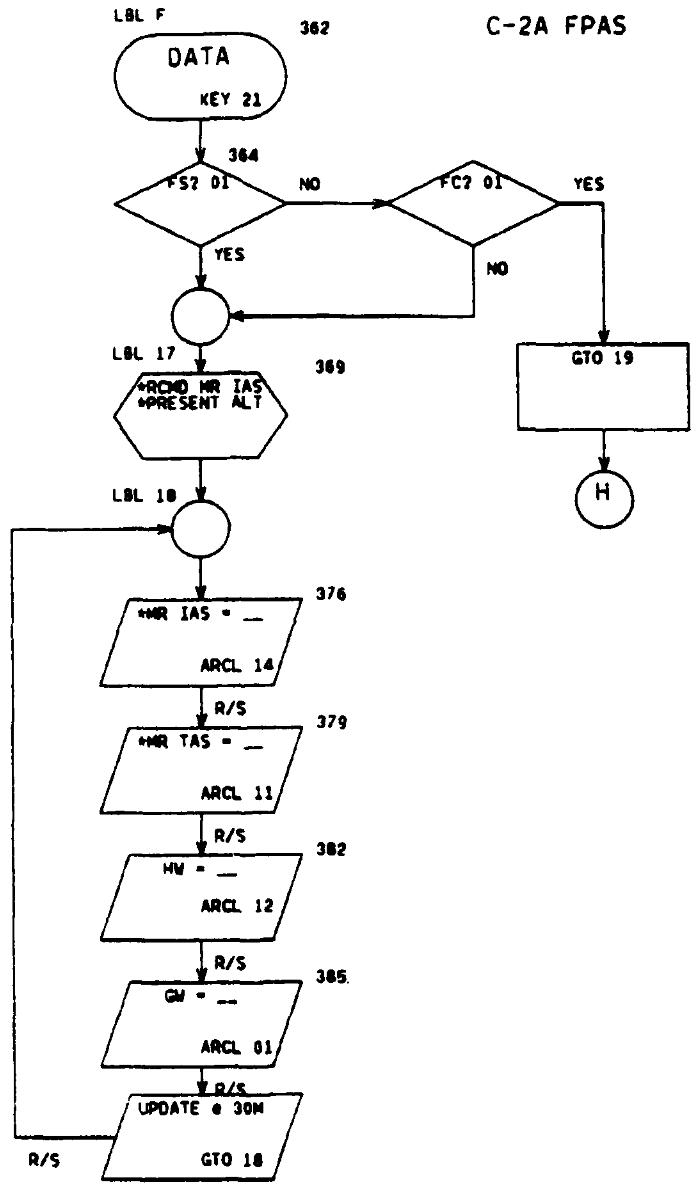
DESCENT ALGORITHM
(cont'd)

C-2A FPAS



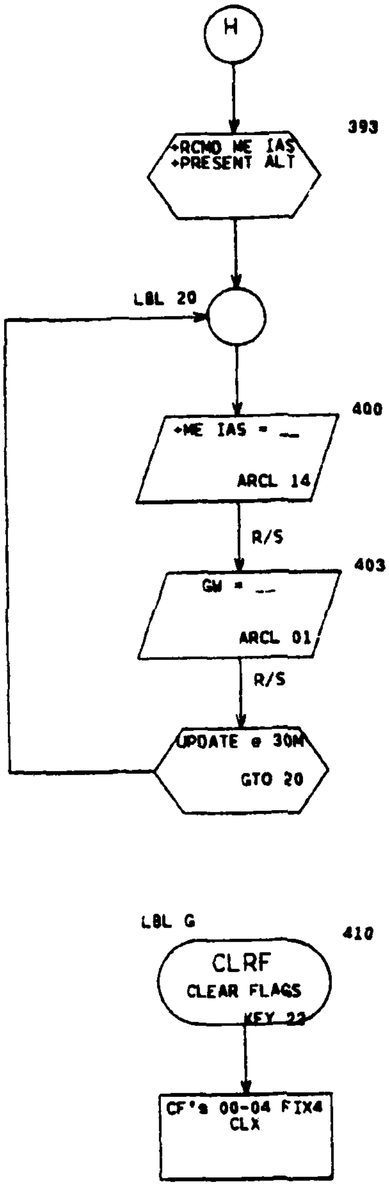
DATA ALGORITHM

C-2A FPAS



DATA ALGORITHM
(cont'd)

C-2A FPAS



C-2A FPAS/HP-41CV Code (June 1982; 1/3)

```
01♦LBL "STF"
02 CF 01
03 CF 02
04 CF 03
05 CF 04
06 CLRG
07 "**C2A FPAS**"
08 AVIEW
09 PSE
10 "BASIC WT = ?"
11 PROMPT
12 STO 00
13 "CARGO WT = ?"
14 PROMPT
15 +
16 STO 00
17 "NO.CREW/PAX=?"
18 PROMPT
19 200
20 *
21 RCL 00
22 +
23 STO 00
24 "PROFILE?"
25 PROMPT
26♦LBL B
27 SF 01
28 CF 02
29 CF 03
30 "**MAX RANGE*"
31 AVIEW
32 PSE
33 XEQ 08
34 RCL 03
35 15
36 -
37 RCL 02
38 198 E-5
39 *
40 +
41 STO 05
42 342 E-10
43 397 E-15
44 RCL 02
45 *
46 -
47 RCL 02
48 *
49 .0019574
50 -
51 RCL 02
52 *
53 146.95
54 +
55 .001235
56 1546 E-12
57 RCL 01
58 *
59 -
60 RCL 01
61 *
62 +
63 RCL 02
64 LN
65 .1518
66 *
67 +
68 STO 13
69♦LBL 01
70 RCL 02
71 -6875 E-9
72 *
73 1
74 +
75 5.2563
76 Y↑X
77 STO 15
78 RCL 04
79 661.7
80 /
81 X↑2
82 .2
83 *
84 1
85 +
86 3.5
87 Y↑X
88 1
89 -
90 RCL 15
91 1/X
92 *
93 1
94 +
95 .286
96 Y↑X
97 1
98 -
99 5
100 *
101 STO 08
102 .2
103 *
104 1
105 +
106 1/X
107 RCL 03
108 *
109 STO 09
110 1936 E-6
111 *
112 RCL 02
113 1500
114 -
115 2112 E-8
116 *
117 +
118 E↑X
119 .982
120 *
121 STO 10
122 FS? 01
123 GTO 03
124 GTO 10
125♦LBL 02
126 RCL 02
127 91 E-6
128 *
129 E↑X
130 1 E-7
131 *
132 RCL 13
133 2.852
134 Y↑X
135 *
136 STO 07
137 RTN
138♦LBL 03
139 RCL 04
140 RCL 10
141 *
142 STO 11
143♦LBL 04
144 "GS,AVAIL? Y/N"
145 PROMPT
146♦LBL E
147 "GS = KTS?"
148 PROMPT
149 STO 16
150 RCL 11
```

C-2A FPAS/HP-41CV Code (June 1982; 2/3)

```
151 RCL 16
152 -
153 STO 12
154 GTO 05
155◆LBL J
156 "INPUT WINDS.."
157 AVIEW
158 PSE
159 "WIND DIR = ?"
160 PROMPT
161 STO 17
162 "WIND VEL = ?"
163 PROMPT
164 STO 18
165 "A/C HDG = ?"
166 PROMPT
167 STO 19
168 RCL 17
169 -
170 ABS
171 COS
172 RCL 18
173 *
174 STO 12
175 RCL 11
176 RCL 12
177 -
178 STO 16
179 RCL 12
180◆LBL 05
181 X<0?
182 GTO 07
183◆LBL 06
184 .5
185 RCL 02
186 1 E-5
187 *
188 -
189 RCL 12
190 *
191 RCL 13
192 +
193 STO 13
194 FS? 03
195 GTO 14
196 GTO 10
197◆LBL 07
198 .3
199 RCL 02
200 5 E-6
201 *
202 -
203 RCL 12
204 *
205 RCL 13
206 +
207 STO 13
208 FS? 03
209 RTN
210 GTO 10
211◆LBL 08
212 "ALT = FT?"
213 PROMPT
214 X<0?
215 10
216 STO 02
217 "OAT = C?"
218 PROMPT
219 STO 03
220 "IAS = KTS?"
221 PROMPT
222 STO 04
223 "FUEL = LBS?"
224 PROMPT
225 RCL 00
226 +
227 STO 01
228 RTN
229◆LBL C
230 SF 02
231 CF 01
232 CF 03
233 "**MAX ENDUR*"
234 AVIEW
235 PSE
236 XEQ 08
237◆LBL 09
238 RCL 01
239 .0016
240 *
241 46
242 +
243 STO 13
244 GTO 01
245◆LBL 10
246 XEQ 02
247 RCL 13
248 RCL 07
249 -
250 STO 14
251 RCL 10
252 *
253 STO 11
254 BEEP
255 "*DATA READY*"
256 PROMPT
257 GTO F
258◆LBL D
259 SF 03
260 CF 01
261 CF 02
262 "*MR DESCENT*"
263 AVIEW
264 PSE
265 "ALT = FT?"
266 PROMPT
267 STO 02
268 "FUEL = LBS?"
269 PROMPT
270 RCL 00
271 +
272 STO 01
273 "L/O ALT = ?"
274 PROMPT
275 STO 20
276 RCL 02
277 -
278 CHS
279 RCL 01
280 35000
281 -
282 134367 E-13
283 *
284 1676 E-6
285 +
286 *
287 FIX 0
288 "DSNT,DIST="
289 ARCL X
290 PROMPT
291◆LBL 11
292 10000
293 RCL 02
294 X>Y?
295 GTO 12
296 RCL 02
297 -1413 E-8
298 *
299 E↑X
300 166.783
```

C-2A/FPAS/HP-41CV Code (June 1982; 3/3)

```
301 *
302 XEQ 16
303 GTO 13
304♦LBL 12
305 RCL 02
306 CHS
307 5077 E-9
308 *
309 E↑X
310 151.503
311 *
312 XEQ 16
313♦LBL 13
314 STO 13
315 RCL 12
316 X>0?
317 GTO 06
318 XEQ 07
319♦LBL 14
320 XEQ 02
321 RCL 13
322 RCL 07
323 -
324 STO 14
325 FS? 04
326 GTO 15
327 " ** NOTE **"
328 AVIEW
329 PSE
330 "UPDTE MRD,IAS"
331 AVIEW
332 PSE
333 "EVERY 2000FT"
334 AVIEW
335 PSE
336 "USE 500 SHP"
337 AVIEW
338 PSE
339 SF 04
340♦LBL 15
341 "MRD IAS="
342 ARCL 14
343 PROMPT
344 "NEW ALT = ?"
345 PROMPT
346 STO 02
347 GTO 11
348♦LBL 16
349 RCL 02
350 2389 E-8
351 *
352 E↑X
353 9014 E-7
354 *
355 RCL 01
356 35000
357 -
358 *
359 +
360 RTN
361♦LBL F
362 FIX 0
363 FS? 01
364 GTO 17
365 FC? 01
366 GTO 19
367♦LBL 17
368 "*RCMD MR IAS"
369 AVIEW
370 PSE
371 "*PRESENT ALT"
372 AVIEW
373 PSE
374♦LBL 18
375 "*MR IAS="
376 ARCL 14
377 PROMPT
378 "*MR TAS="
379 ARCL 11
380 PROMPT
381 "*HW = "
382 ARCL 12
383 PROMPT
384 "GW = "
385 ARCL 01
386 PROMPT
387 "UPDATE e 30M"
388 AVIEW
389 PSE
390 GTO 18
391♦LBL 19
392 "+RCMD ME IAS"
393 AVIEW
394 PSE
395 "+PRESENT ALT"
396 AVIEW
397 PSE
398♦LBL 20
399 "+ME IAS="
400 ARCL 14
401 PROMPT
402 "GW = "
403 ARCL 01
404 PROMPT
405 "UPDATE e 30M"
406 AVIEW
407 PSE
408 GTO 20
409♦LBL G
410 CF 00
411 CF 01
412 CF 02
413 CF 03
414 CF 04
415 FIX 4
416 CLX
417 END
```

5.1.3 Governing Equations

As in the case for the E-2B, equations common to the E-2C program will not be listed. Headwind corrections are the same for the C-2A as the E-2C.

Max Range Calibrated Airspeed: MRCAS = f(PA,GW)

```
MRCAS = 146.95 - .0019574(PA) + .001235(GW)
        + 342E-10(PA)**2 - 397E-15(PA)**3 -
        - 1546E-12(GW)**2 + .1518LN(PA)
```

Max Endurance Calibrated Airspeed: MECAS = f(GW)

```
MECAS = 46 + .0016(GW)
```

Descent Distance: DD = f(PA,LOPA,GW)

```
DD = (PA-LOPA)((GW-35000)(134367E-13)+1676E-6)
```

Max Range Descent CAS (>10000): MRDCAS = f(PA,GW)

```
MRDCAS = 151.503exp((-5077E-9)(PA))
         + (GW-35000)*9014E-7exp((2389E-8)(PA))
```

Max Range Descent CAS (<10000): MRDCAS = f(PA,GW)

```
MRDCAS = 166.783exp((-1413E-8)(PA))
         + (GW-35000)*9014E-7exp((2389E-8)(PA))
```

5.2 THE C-2A BINGO PROGRAM

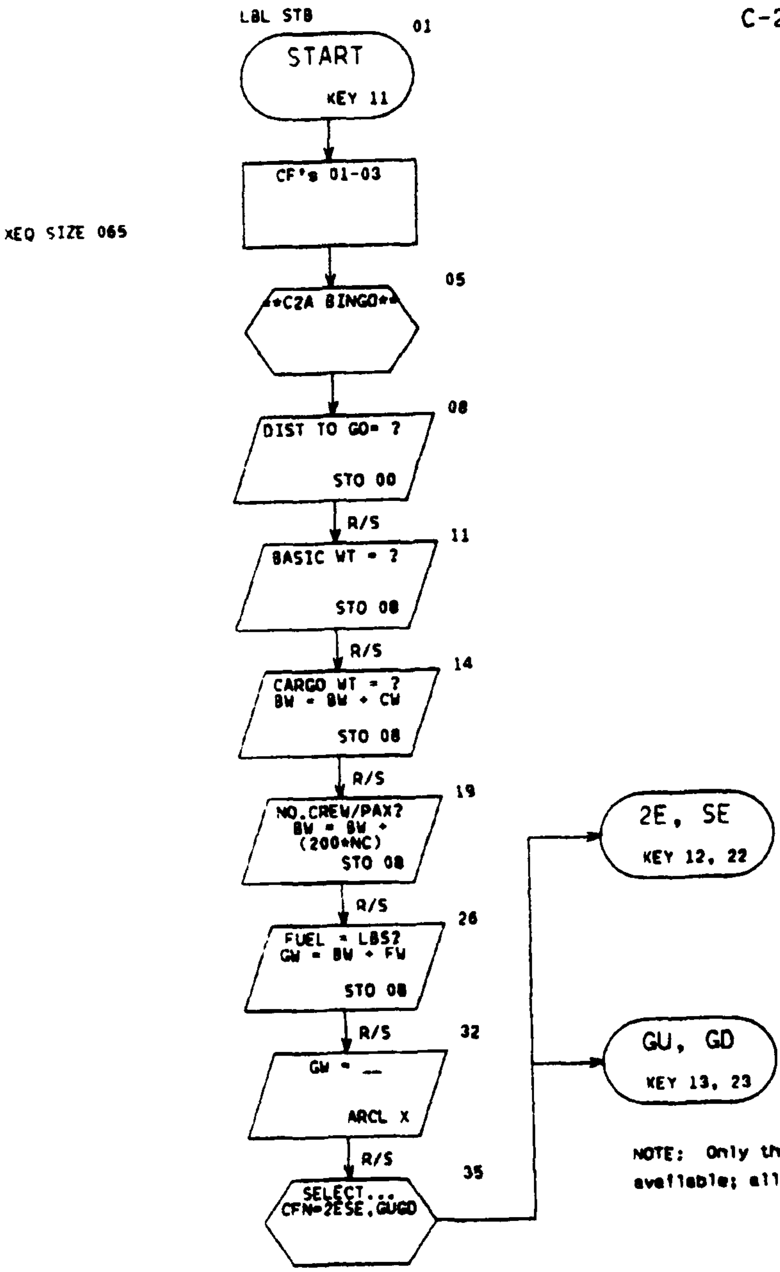
There are only three configurations to choose from when setting up a BINGO profile for the C-2A. No choices are allowed for possible stuck flap situations. The three configurations allowed are: 2EGUFU, 2EGDFU, and SEGUFU.

It is interesting to note, also, that the fuel required values for the C-2A are not rounded off to the nearest five pound increment, and instructions are included on how to adjust the fuel required for variations in weight above or below 45000 pounds gross weight. The C-2A BINGO program reflects all of these differences while still retaining the basic operating principles of the E-2C and E-2B programs.

Program initiation is somewhat more extensive than the other two programs since the C-2A program requires gross weight. The Sample Program Operation section presents a detailed example of how the program works.

The following flowcharts record the algorithm for the C-2A BINGO program. Line numbers next to function blocks reference line numbers in the code listing that follows the flowcharts.

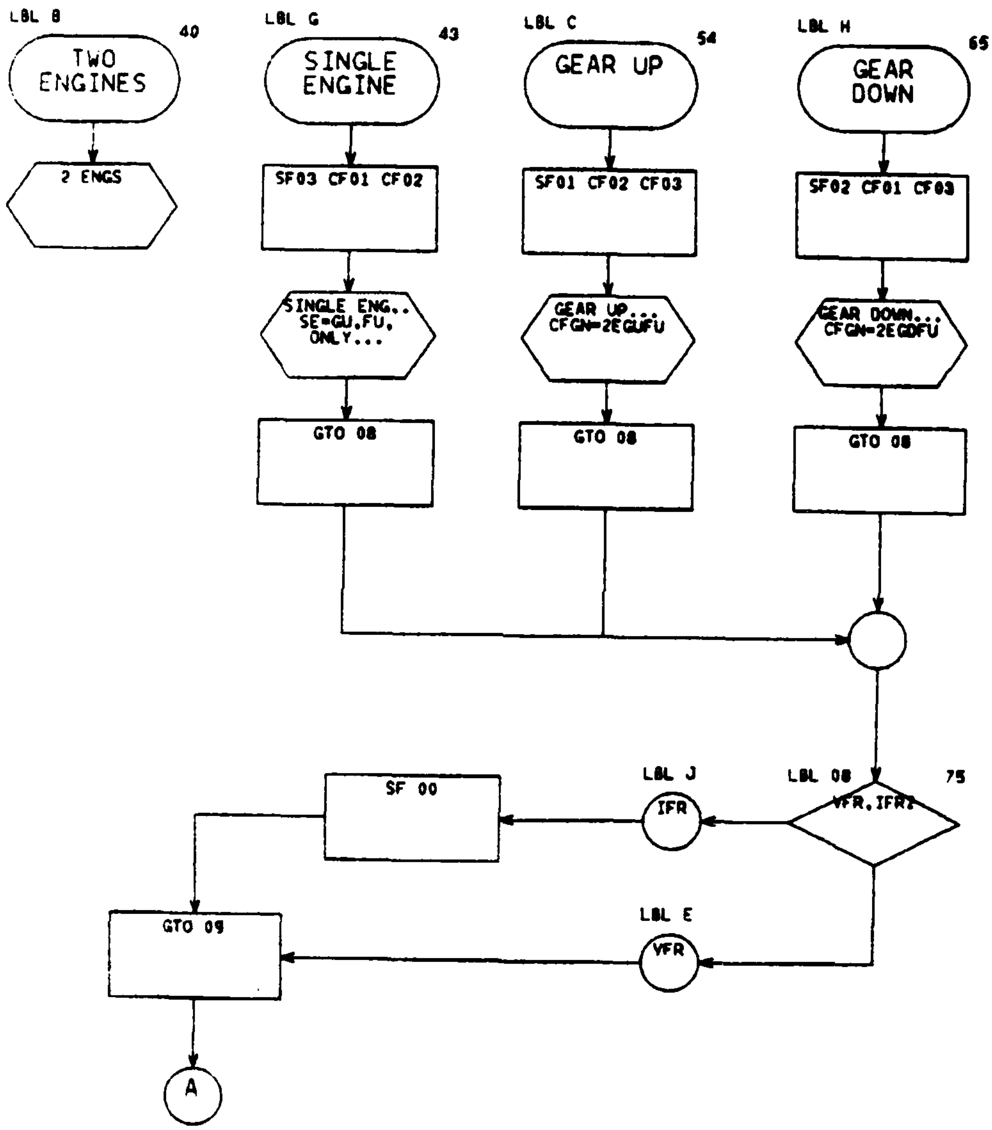
C-2A BINGO



NOTE: Only three configurations available; all => flaps up

1/6

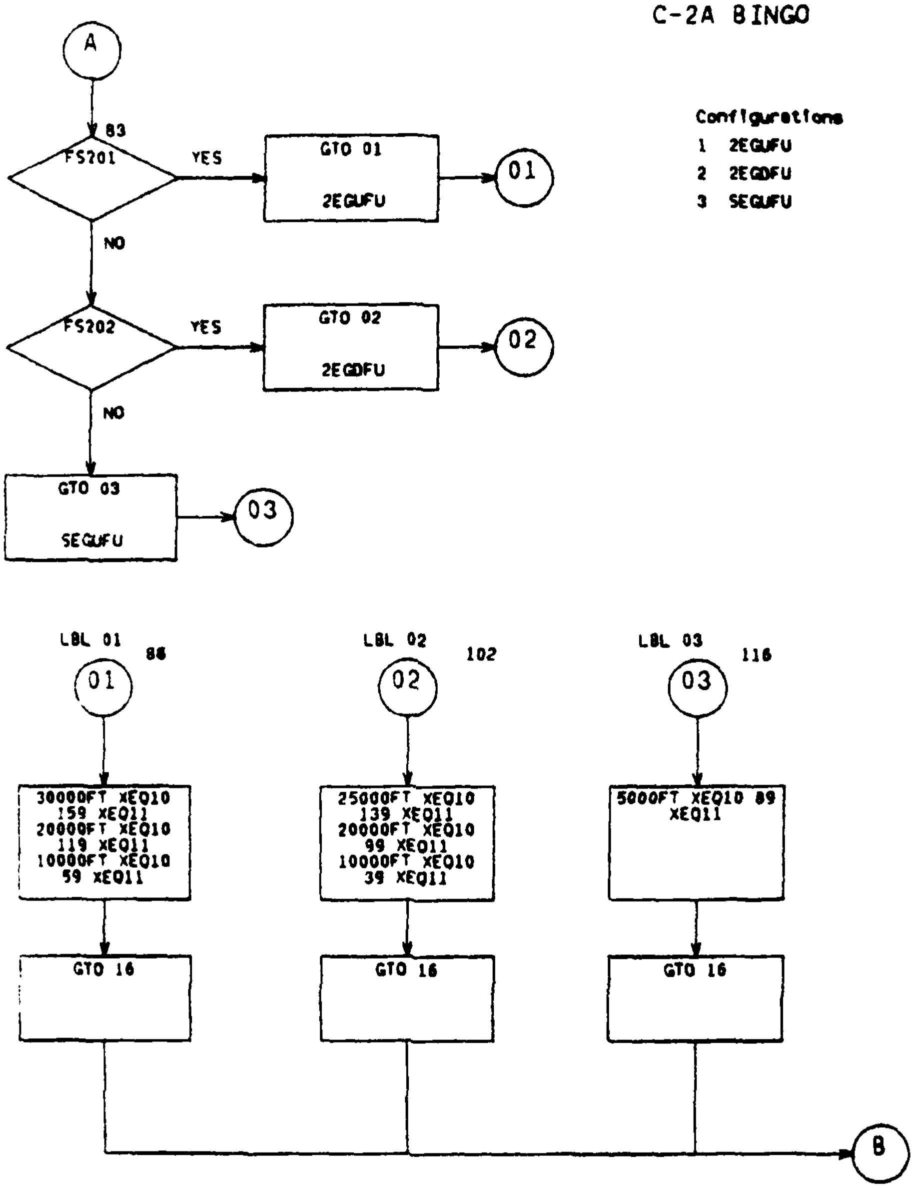
C-2A BINGO


LBL B
40
TWO ENGINES
2 ENGS
LBL G
43
SINGLE ENGINE
SF03 CF01 CF02
SINGLE ENG.. SE=GU,FU, ONLY...
GTO 08
LBL C
54
GEAR UP
SF01 CF02 CF03
GEAR UP... CFGN=2EGUFU
GTO 08
LBL H
65
GEAR DOWN
SF02 CF01 CF03
GEAR DOWN... CFGN=2EGDFU
GTO 08
LBL 08
75
VFR,IFR?
LBL J
IFR
SF 00
LBL E
VFR
GTO 09
A

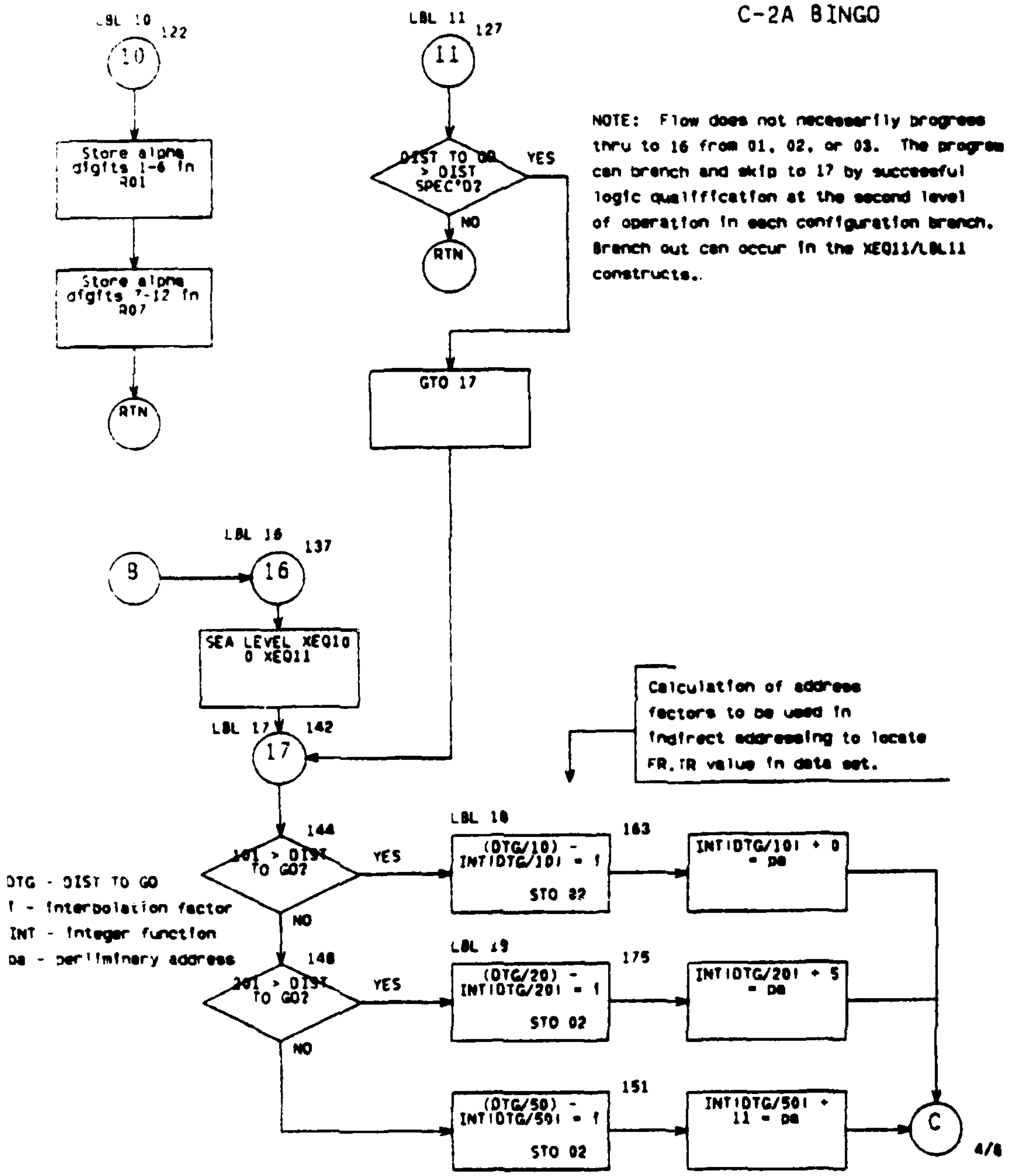
C-2A BINGO

Configurations

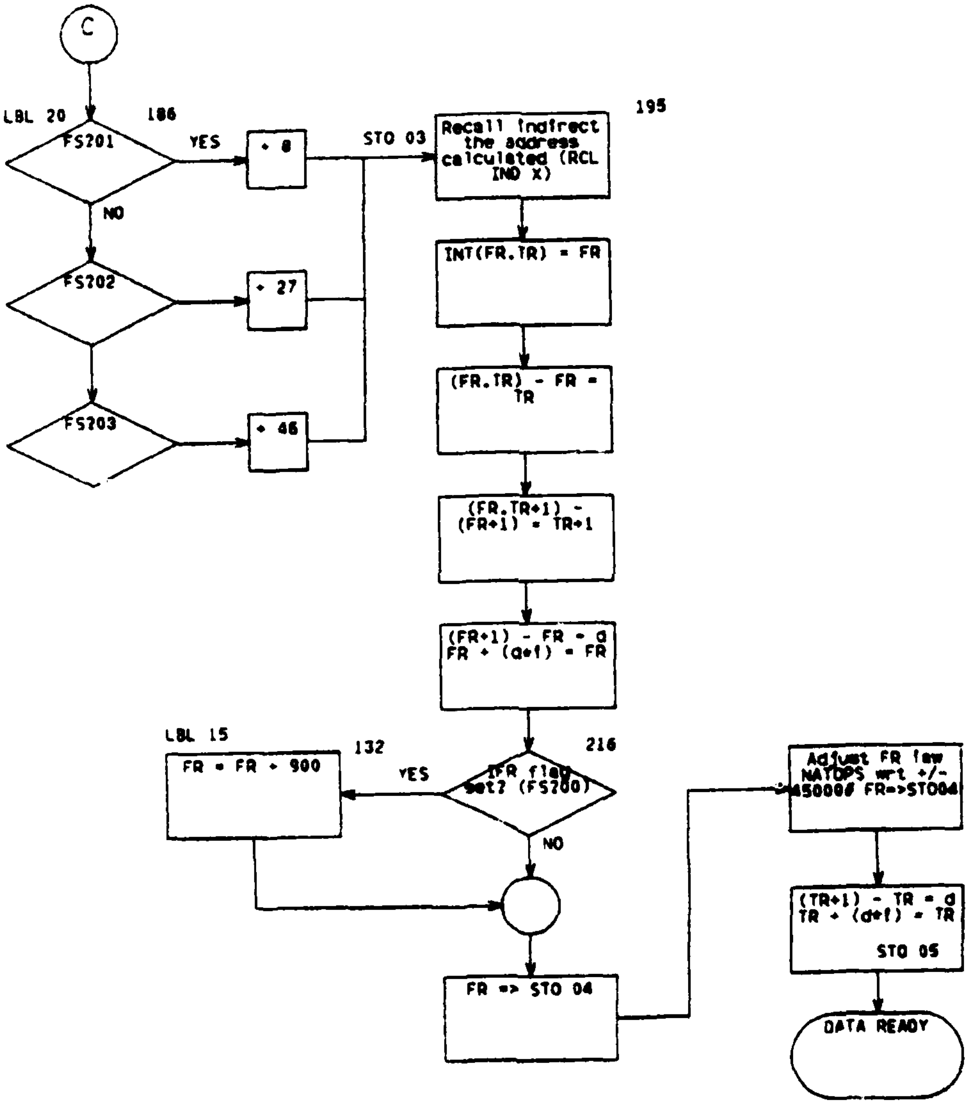
1 2EGUFU
2 2EGDFU
3 SEGUFU



C-2A BINGO

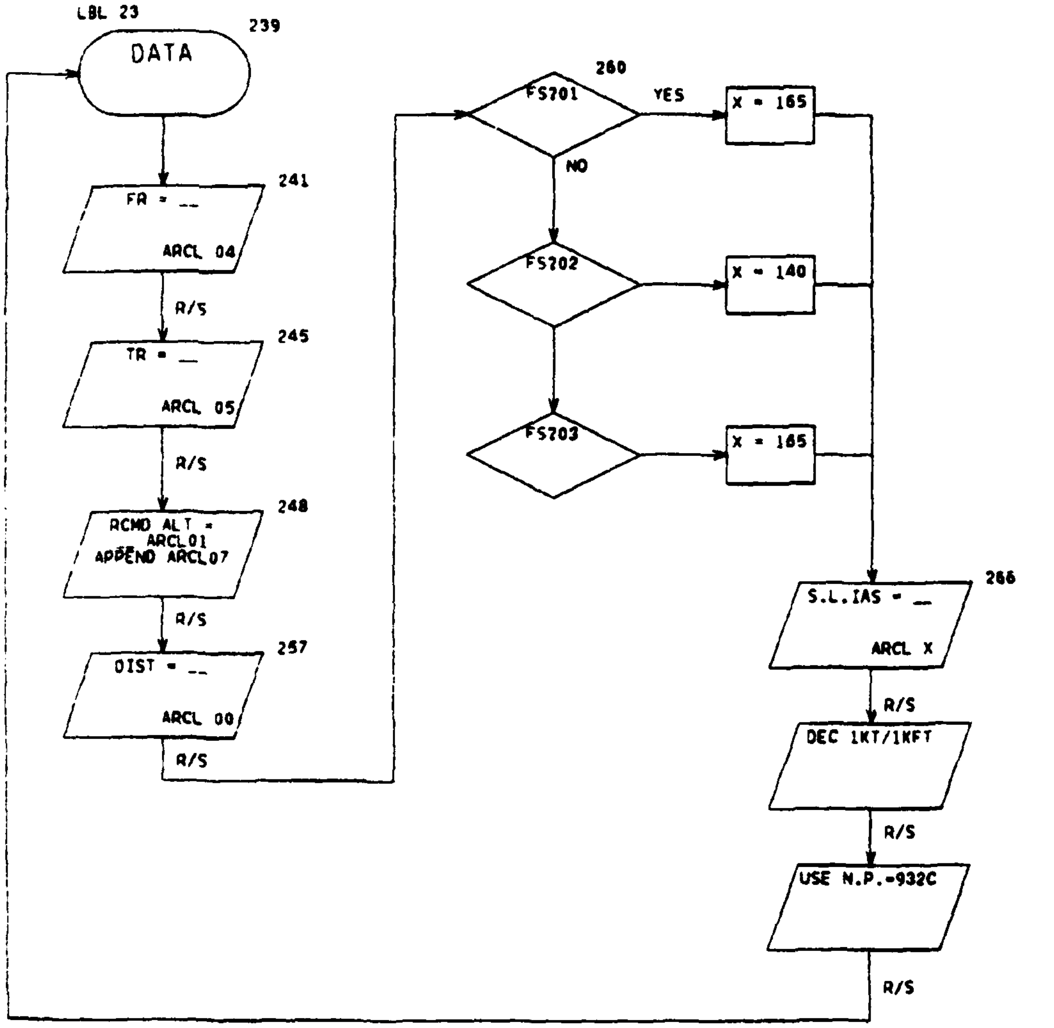

LBL 10
122
10
Store alpha digits 1-6 in R01
Store alpha digits 7-12 in R07
RTN
LBL 11
127
11
DIST TO GO > DIST SPEC'D?
YES
NO
RTN
GTO 17
NOTE: Flow does not necessarily progress thru to 16 from 01, 02, or 03. The program can branch and skip to 17 by successful logic qualification at the second level of operation in each configuration branch. Branch out can occur in the XEQ11/LBL11 constructs.
LBL 16
137
B
16
SEA LEVEL XEQ10
0 XEQ11
LBL 17
142
17
Calculation of address factors to be used in indirect addressing to locate FR,TR value in data set.
144
10! > DIST TO GO?
YES
NO
DTG - DIST TO GO
f - interpolation factor
INT - integer function
pa - perliminary address
LBL 18
163
(DTG/10) - INT(DTG/10) = f
STO 02
INT(DTG/10) + 0 = pa
148
20! > DIST TO GO?
YES
NO
LBL 19
175
(DTG/20) - INT(DTG/20) = f
STO 02
INT(DTG/20) + 5 = pa
151
(DTG/50) - INT(DTG/50) = f
STO 02
INT(DTG/50) + 11 = pa
C
4/6

C-2A BINGO



C
LBL 20
186
FS201
YES
NO
÷ 8
FS202
÷ 27
FS203
÷ 46
STO 03
195
Recall indirect the address calculated (RCL IND X)
INT(FR.TR) = FR
(FR.TR) - FR = TR
(FR.TR+1) - (FR+1) = TR+1
(FR+1) - FR = d
FR + (d*f) = FR
LBL 15
132
FR = FR + 900
YES
216
IFR flag set? (FS200)
NO
FR => STO 04
219
Adjust FR iaw NATOPS wrt +/- 45000# FR=>STO04
(TR+1) - TR = d
TR + (d*f) = TR
STO 05
DATA READY

C-2A BINGO


LBL 23
239
DATA
241
FR = __
ARCL 04
R/S
245
TR = __
ARCL 05
R/S
248
RCMD ALT =
ARCL 01
APPEND ARCL 07
R/S
257
DIST = __
ARCL 00
R/S
260
FS?01
YES
NO
X = 165
FS?02
X = 140
FS?03
X = 165
266
S.L.IAS = __
ARCL X
R/S
DEC 1KT/1KFT
R/S
USE N.P.=932C
R/S

C-2A BINGO/HP-41CV Code (June 1982; 1/3)

```
01♦LBL "STB"
02 CF 01
03 CF 02
04 CF 03
05 "**C2A BINGO*"
06 AVIEW
07 PSE
08 "DIST TO GO ?"
09 PROMPT
10 STO 00
11 "BASIC WT = ?"
12 PROMPT
13 STO 08
14 "CARGO WT = ?"
15 PROMPT
16 RCL 08
17 +
18 STO 08
19 "NO.CREW/PAX=?"
20 PROMPT
21 200
22 *
23 RCL 08
24 +
25 STO 08
26 "FUEL = LBS?"
27 PROMPT
28 RCL 08
29 +
30 STO 08
31 FIX 0
32 "GW = "
33 ARCL X
34 PROMPT
35 "SELECT.."
36 AVIEW
37 PSE
38 "CFGN=2E:SE,GU:D"
39 PROMPT
40♦LBL B
41 "2 ENGS"
42 PROMPT
43♦LBL G
44 SF 03
45 CF 01
46 CF 02
47 "SINGLE ENG..."
48 AVIEW
49 PSE
50 "SE=GU,FU,ONLY.."
51 AVIEW
52 PSE
53 GTO 08
54♦LBL C
55 SF 01
56 CF 02
57 CF 03
58 "GEAR UP.."
59 AVIEW
60 PSE
61 "CFGN=2EGUFU.."
62 AVIEW
63 PSE
64 GTO 08
65♦LBL H
66 SF 02
67 CF 01
68 CF 03
69 "GEAR DOWN.."
70 AVIEW
71 PSE
72 "CFGN=2EGDFU.."
73 AVIEW
74 PSE
75♦LBL 08
76 " VFR, IFR ?"
77 PROMPT
78♦LBL E
79 GTO 09
80♦LBL J
81 SF 00
82♦LBL 09
83 FS? 01
84 GTO 01
85 FS? 02
86 GTO 02
87 GTO 03
88♦LBL 01
89 "30000 FT"
90 XEQ 10
91 159
92 XEQ 11
93 "20000 FT"
94 XEQ 10
95 119
96 XEQ 11
97 "10000 FT"
98 XEQ 10
99 59
100 XEQ 11
101 GTO 16
102♦LBL 02
103 "25000 FT"
104 XEQ 10
105 139
106 XEQ 11
107 "20000 FT"
108 XEQ 10
109 99
110 XEQ 11
111 "10000 FT"
112 XEQ 10
113 39
114 XEQ 11
115 GTO 16
116♦LBL 03
117 " 5000 FT"
118 XEQ 10
119 89
120 XEQ 11
121 GTO 16
122♦LBL 10
123 ASTO 01
124 ASHF
125 ASTO 07
126 RTN
127♦LBL 11
128 RCL 00
129 X>Y?
130 GTO 17
131 RTN
132♦LBL 15
133 CF 00
134 900
135 +
136 RTN
137♦LBL 16
138 "  SEA LEVEL"
139 XEQ 10
140 0
141 XEQ 11
142♦LBL 17
143 RCL 00
144 101
145 X>Y?
146 GTO 18
147 X<>Y
148 201
149 X>Y?
150 GTO 19
```

C-2A BINGO/HP-41CV Code (June 1982; 2/3)

```
151 RCL 00
152 50
153 /
154 ENTER↑
155 INT
156 STO 03
157 -
158 STO 02
159 RCL 03
160 11
161 GTO 20
162♦LBL 18
163 RCL 00
164 10
165 /
166 ENTER↑
167 INT
168 STO 03
169 -
170 STO 02
171 RCL 03
172 0
173 GTO 20
174♦LBL 19
175 RCL 00
176 20
177 /
178 ENTER↑
179 INT
180 STO 03
181 -
182 STO 02
183 RCL 03
184 5
185♦LBL 20
186 +
187 FS? 01
188 8
189 FS? 02
190 27
191 FS? 03
192 46
193 +
194 STO 03
195 RCL IND X
196 ENTER↑
197 INT
198 STO 04
199 -
200 STO 05
201 1
202 ST+ 03
203 RCL IND 03
204 ENTER↑
205 INT
206 STO 06
207 -
208 STO 03
209 RCL 06
210 RCL 04
211 -
212 RCL 02
213 *
214 RCL 04
215 +
216 FS? 00
217 XEQ 15
218 STO 04
219 RCL 08
220 45000
221 -
222 90000
223 /
224 RCL 04
225 *
226 RCL 04
227 +
228 STO 04
229 RCL 03
230 RCL 05
231 -
232 RCL 02
233 *
234 RCL 05
235 +
236 10
237 *
238 STO 05
239♦LBL 23
240 FIX 0
241 " FR = "
242 ARCL 04
243 FIX 2
244 PROMPT
245 " TR = "
246 ARCL 05
247 PROMPT
248 "RCMND ALT = "
249 AVIEW
250 PSE
251 CLA
252 ARCL 01
253 "├"
254 ARCL 07
255 PROMPT
256 FIX 0
257 " DIST = "
258 ARCL 00
259 PROMPT
260 FS? 01
261 165
262 FS? 02
263 140
264 FS? 03
265 165
266 "S.L. IAS = "
267 ARCL X
268 PROMPT
269 "DEC 1KT/1KFT"
270 PROMPT
271 "USE N.P.= 932C"
272 PROMPT
273 GTO 23
274 .END.
```

```
R00=  0.000
R01=  1.000
R02=  2.000
R03=  3.000
R04=  4.000
R05=  5.000
R06=  6.000
R07=  7.000
R08=  8.000
R09=  921.003
R10=  1,044.006
R11=  1,166.009
R12=  1,288.012
R13=  1,410.015
R14=  1,506.021
R15=  1,602.024
R16=  1,699.027
R17=  1,795.030
R18=  1,891.032
R19=  2,053.041
R20=  2,207.046
R21=  2,356.102
R22=  2,485.107
```

C-2A BINGO/HP-41CV Code (June 1982; 3/3)

```
R23=  2,621.111
R24=  2,945.123
R25=  3,265.135
R26=  3,592.146
R27=  3,906.158
R28=  961.004
R29=  1,123.007
R30=  1,284.011
R31=  1,436.015
R32=  1,559.018
R33=  1,683.022
R34=  1,806.025
R35=  1,930.028
R36=  2,053.032
R37=  2,171.034
R38=  2,371.040
R39=  2,570.046
R40=  2,763.051
R41=  2,955.057
R42=  3,141.103
R43=  3,596.117
R44=  4,063.132
R45=  4,505.146
R46=  4,939.200
R47=  897.004
R48=  994.007
R49=  1,091.010
R50=  1,188.014
R51=  1,284.018
R52=  1,382.021
R53=  1,478.025
R54=  1,575.029
R55=  1,662.041
R56=  1,751.044
R57=  1,926.051
R58=  2,101.058
R59=  2,276.105
R60=  2,450.111
R61=  2,626.118
R62=  3,062.135
R63=  3,496.152
R64=  3,927.209
R65=  4,355.226
```

5.3 SAMPLE PROGRAM OPERATION (C-2A)

5.3.1 FPAS

Prompt	Response	
	START	R/S
C2A FPAS		
BASIC WT = ?	31000	R/S
CARGO WT = ?	2500	R/S
NO.CREW/PAX=?	8	R/S
PROFILE?	RANGE	R/S
**MAX RANGE*		
ALT = FT?	25000	R/S
OAT = C?	-15	R/S
IAS = KTS?	165	R/S
FUEL = LBS?	8000	R/S
GS,AVAIL? Y/N	NO	KEY 25
INPUT WINDS..		
WIND DIR = ?	300	R/S
WIND VEL = ?	45	R/S
A/C HDG = ?	275	R/S
DATA READY		R/S or KEY 21
*RCMD MR IAS		
*PRESENT ALT		
*MR IAS = 173		R/S
*MR TAS = 271		R/S
*HW = 41		R/S
GW = 43100		R/S
UPDATE e 30M		R/S to repeat data
	ENDUR	KEY 13
**MAX ENDUR*		
ALT = FT?	20000	R/S
OAT = C?	-10	R/S
IAS = KTS?	150	R/S
FUEL = LBS?	5000	R/S
DATA READY		R/S or KEY 21
+RCMD ME IAS		
+PRESENT ALT		
+ME IAS = 110		R/S

```
GW = 40100                          R/S
UPDATE @ 30M                        R/S to repeat data

                          DESCENT   KEY 14
*MR DESCENT*
ALT = FT?                  26000    R/S
FUEL = LBS?                 7000    R/S
L/O ALT = ?                 1000    R/S
DSND,DIST=44                        R/S
 ** NOTE **
UPDTE MRD,IAS
EVERY 2000FT
USE 500 SHP
MRD IAS = 153                       R/S
NEW ALT = ?                24000    R/S
MRD IAS = 154                       R/S etc.
```

5.3.2 BINGO

```
 Prompt                    Response
                          START   R/S
**C2A BINGO*
DIST TO GO ?                 85   R/S
BASIC WT = ?              31000   R/S
CARGO WT = ?               7000   R/S
NO.CREW/PAX=?                10   R/S
FUEL = LBS?                4500   R/S
GW = 44500                        R/S
SELECT..
CFGN=2E:SE,GU:D              2E
2 ENGS                       GU
GEAR UP..
CFGN=2EGUFU..
VFR, IFR ?                  IFR
FR = 2632                         R/S
TR = 0.29                         R/S
RCMND ALT =
10000 FT                          R/S
```

DIST = 85	R/S
S.L. IAS = 165	R/S
DEC 1KT/1KFT	R/S
USE N.P. = 932C	R/S to repeat data

5.3.3 Crosswind Landing

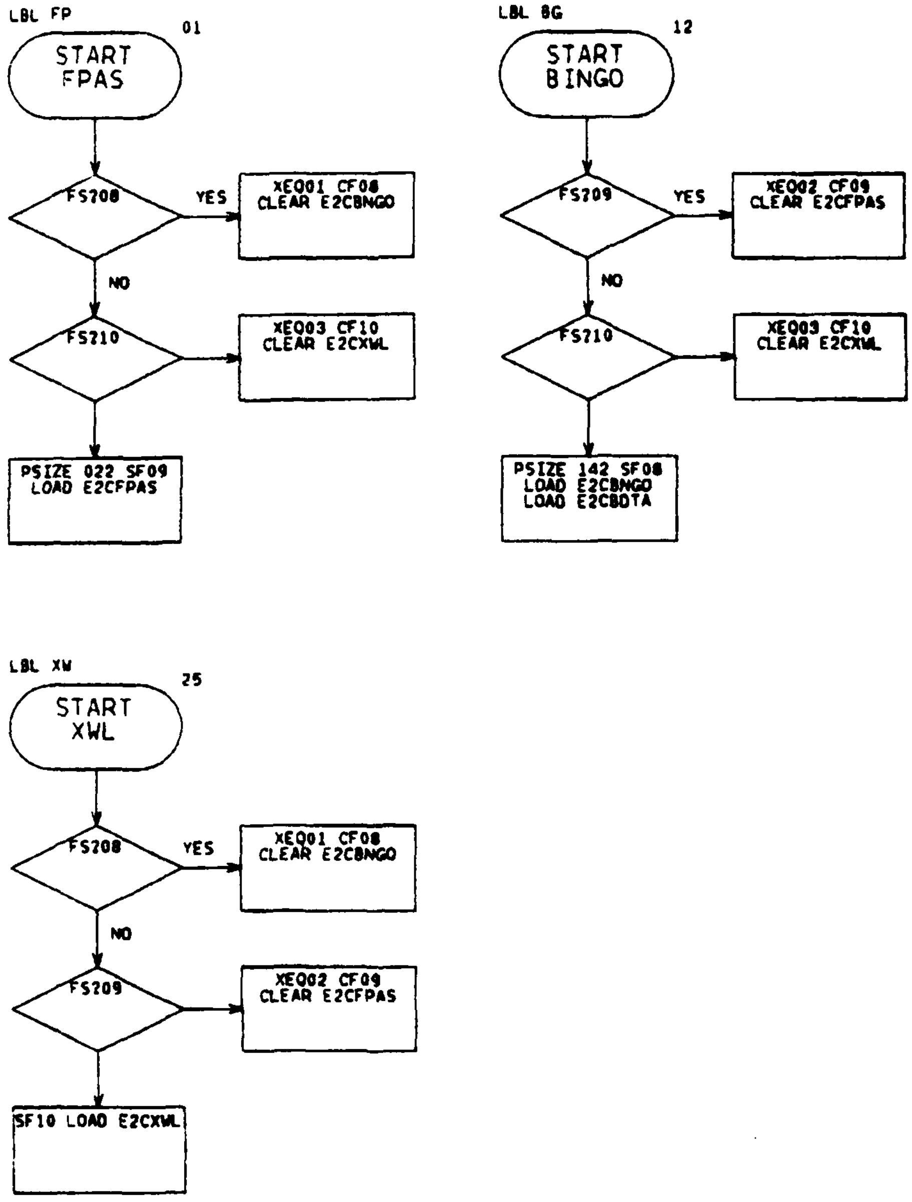
Refer to section describing program operation for the E-2C.

Chapter VI
MAIN MEMORY ACCESSING PROGRAM

Theory of operation is simple and straight forward. One of three programs loaded in main memory should have set one of flags 8, 9, or 10 when loaded. When a new program is requested, a program check for the flag already set calls a subroutine that clears the loaded program. The new program is then called and loaded.

The next page is a flowchart for this algorithm, and the next page a code listing.

MAIN MEMORY ACCESSING PROGRAM



MMAP/HP-41CV Code (June 1982; 1/1)

```
01+LBL "FP"
02 FS? 08
03 XEQ 01
04 FS? 10
05 XEQ 03
06 022
07 PSIZE
08 SF 09
09 "E2CFPAS"
10 GETP
11 STOP
12+LBL "BG"
13 FS? 09
14 XEQ 02
15 FS? 10
16 XEQ 03
17 142
18 PSIZE
19 SF 08
20 "E2CBNGO"
21 GETP
22 "E2CBDTA"
23 GETR
24 STOP
25+LBL "XW"
26 FS? 08
27 XEQ 01
28 FS? 09
29 XEQ 02
30 SF 10
31 "E2CXWL"
32 GETP
33 STOP
34+LBL 01
35 CF 08
36 "STB"
37 PCLPS
38 RTN
39+LBL 02
40 CF 09
41 "STF"
42 PCLPS
43 RTN
44+LBL 03
45 CF 10
46 "XWL"
47 PCLPS
48 RTN
49 END
```

```
01+LBL "FP"
02 FS? 08
03 XEQ 01
04 FS? 10
05 XEQ 03
06 022
07 PSIZE
08 SF 09
09 "E2BFPAS"
10 GETP
11 STOP
12+LBL "BG"
13 FS? 09
14 XEQ 02
15 FS? 10
16 XEQ 03
17 142
18 PSIZE
19 SF 08
20 "E2BBNGO"
21 GETP
22 "E2BBDTA"
23 GETR
24 STOP
25+LBL "XW"
26 FS? 08
27 XEQ 01
28 FS? 09
29 XEQ 02
30 SF 10
31 "E2BXWL"
32 GETP
33 STOP
34+LBL 01
35 CF 08
36 "STB"
37 PCLPS
38 RTN
39+LBL 02
40 CF 09
41 "STF"
42 PCLPS
43 RTN
44+LBL 03
45 CF 10
46 "XWL"
47 PCLPS
48 RTN
49 END
```

```
01+LBL "FP"
02 FS? 08
03 XEQ 01
04 FS? 10
05 XEQ 03
06 022
07 PSIZE
08 SF 09
09 "C2AFPAS"
10 GETP
11 STOP
12+LBL "BG"
13 FS? 09
14 XEQ 02
15 FS? 10
16 XEQ 03
17 65
18 PSIZE
19 SF 08
20 "C2ABNGO"
21 GETP
22 "C2ABDTA"
23 GETR
24 STOP
25+LBL "XW"
26 FS? 08
27 XEQ 01
28 FS? 09
29 XEQ 02
30 SF 10
31 "C2AXWL"
32 GETP
33 STOP
34+LBL 01
35 CF 08
36 "STB"
37 PCLPS
38 RTN
39+LBL 02
40 CF 09
41 "STF"
42 PCLPS
43 RTN
44+LBL 03
45 CF 10
46 "XWL"
47 PCLPS
48 RTN
49 END
```

Chapter VII
CALCULATOR SHIELDING

During the course of this project, an opportunity arose in early May 1982 to travel to RVAW-110 at NAS Miramar to try several methods of protecting the HP-41CV from electromagnetic interference (EMI) in the E-2. The EMI was discovered to adversely affect the HP-41 during an informal test flight in September 1981. In the intervening period, discussions were initiated with customer support engineers at Hewlett-Packard to seek a solution to the problem.

Most of their suggestions centered around providing shielding for the calculator. The HP-41 uses a type of circuitry technology referred to as CMOS. CMOS is sensitive to external EMI. Program flags in the HP-41 are apparently set by the electric field incident in the cockpit[17] whenever the main beam of the radar passes. Based on a knowledge of the calculator, it is reasonable to assume that one of those flags turns the calculator off. No damage occurs when this happens, either physically or to memory and circuitry. But the calculator can only be restored to operation by reseating the batteries.

---

[17] Grumman engineers estimate the potential of this field at 30 to 50 volts per meter in certain areas of the cockpit, most notably near windows and mirrors.

The Hewlett-Packard engineers suggested that consideration be given to conformal coatings for the calculator's circuits. Conformal coating is an epoxy like resin formed around circuit parts. The resin can then be coated with various shielding materials. While this method is feasible, it would also be impractical. Any warranties would be invalidated and repair becomes virtually impossible.

The only other way to protect the HP-41 is with some form of external shielding. There are two areas of the calculator that are suspected of causing the most problems: a logic board directly behind the key pad, and a display driver hybrid behind the LCD.

The HP engineers sent two types of special purpose plastic bags to try in a shielding experiment. The first was an anti-static bag, the type used to enclose various electrical parts for shipment. The second was a nickel laminated plastic bag.

Other shielding ideas consisted of aluminum foil wraps with appropriate cutouts and a metal mask similar in design to the overlay masks used on the calculator to label special use keys.

During the flight in early may, the calculator was unwrapped from a full aluminum foil shield and found to be in operating order. A second wrap, below the first, exposed only those areas of the calculator needed to view output and operate the keys. The stainless steel mask, manufactured by shop personnel at NPS, covered the keyboard area. The calculator was held in the vicinity of the kneeboard while the foil was removed in sections from the bottom up. The calculator continued to work the entire time; the steel mask remained in place. It appeared at this point that previous apprehensions concerning failure of the calculator in the E-2's EMI environment were unfounded. However, by placing the calculator against the overhead hatch (an obvious extreme), the phenomena previously explained was duplicated. The batteries were reseated and operation restored.

At this point, the anti-static bags were used and found to be totally unacceptable for shielding the calculator. The nickel laminated bags, however, worked quite well. Only one was required. These bags will be used again in future efforts if new shielding problems arise. Their main disadvantage, however, is the dark, translucent coloring that makes them somewhat difficult to see through. Lighting experiments would have to be conducted to determine the amount of night lighting required to use them. Day light use appears to be no problem.

None of the above experimentation could be examined under the light of strict compliance with scientific principles. No formal or rigorous treatment of electromagnetic propagation theory has been delved into. The work performed, however, is sufficient to warrant continued work with the HP-41CV in the E-2 cockpit. Original fears that the calculator would not work at all were unfounded. Currently, it appears that the only shielding actually required is the stainless steel mask. This arrangement probably serves to protect the logic board behind the key pad. It is also important to point out that the Extended Functions module and two Extended Memory modules were installed. The presence of these modules may have had a net shielding effect for the display driver hybrid behind the LCD.

Chapter VIII
PROGRAM LOADING INSTRUCTIONS

Basic to understanding the instructions listed here is a familiarity with the HP-41CV. Chapter I gives a brief overview, but users are encouraged to read documentation provided with the calculator by Hewlett-Packard and become familiar with programming and basic functions. The HP-41CV is easier to learn than most programmable calculators and the RPN logic should not be a deterent. Once learned, RPN is easier than standard operating procedures on other calculators.

It is assumed that all programs for one particular aircraft are loaded on magnetic storage cards (magcards). The total number of magcards varies for each aircraft, but the operating principles are the same. In those cases where there is an aircraft or program dependent label or instruction, that instruction will be written in an E-2C/E-2B/C-2A format.

It is also assumed that one Extended Functions/Memory module and two Extended Memory modules are mounted in the calculator. Read the HP instructions carefully so that modules are located in the proper position. The following figure is an end view of the calculator with a suggested mounting order. Attention to proper mounting order is important.

X FUNCTIONS	X MEMORY
X MEMORY	

Figure 2: Suggested Module Mounting Order

Without the modules, the calculator will accomodate only the FPAS or the BINGO program, not both. XWL could possible loaded with either one. More than one calculator would be required to have all programs without the modules. (Using modules is less expensive).

If the program is not already loaded on magcards, manual entry will be required.[18] The FPAS and BINGO programs each involve several hundred separate entries.[19] Once loaded, appropriate user labels will have to be assigned; refer to program code.

In the following instructions, an underlined label refers to a function/mode key, boldface refers to alpha/numeric entries.

---

[18] See appendix A for data loading instructions for BINGO data.

[19] Users desiring a set of magcards are encouraged to send about 20 blank cards for loading from the master program. Addresses are listed in Appendix B.

1. Calculator on, set USER mode. USER mode should be on during the entire procedure.
2. XEQ SIZE 022 (ie. XEQ ALPHA SIZE 022)
3. Insert each magcard in order, side one, then side two.
4. After the last card is loaded, the window displays "WORKING" to indicate that program entry is complete and the code is being packed.
5. ALPHA STF,E2CFPAS/STF,E2BFPAS/STF,C2AFPAS ALPHA; XEQ SAVEP (This instuction loads FPAS into Extended Memory).
6. XEQ EMDIR The display should respond with "E2CFPAS/E2BFPAS/C2AFPAS nnn", indicating successful loading of the program into Extended Memory).
7. XEQ CLP STF (Clear FPAS from main memory).
8. XEQ SIZE 141
9. Load program cards for the BINGO program.
10. ALPHA CLR STB,E2CBNGO/STB,E2BBNGO/STB,C2ABNGO ALPHA
11. XEQ SAVEP
12. XEQ CLP STB
13. 0.140/0.140/0.065 ENTER
14. XEQ RDTAX (After ALPHA pressed, display prompts for BINGO data cards).
15. ALPHA CLR E2CBDTA/E2BBDTA/C2ABDTA ALPHA
16. 141/141/66 ENTER
17. XEQ CRFLD
18. XEQ SAVER
19. XEQ CLRG
20. Load XWL program card.
21. ALPHA CLR XWL,E2CXWL/XWL,E2BXWL/XWL,C2AXWL ALPHA
22. XEQ SAVEP
23. XEQ CLP XWL
24. Load control program card.
25. SHIFT GTO.. (This procedure is very important. The calculator will pack the control program and place an END statement at the end of the code. Failure to do this will result in some very strange responses from the calculator)

The calculator is now fully loaded and ready to run. Refer to the section in each chapter regarding how to access certain programs for correct operation.

Chapter IX
KNEEBOARD DESIGN

When this project was first proposed to the NADC engineer[20] in charge of sponsoring FPAS efforts, a request was made to look into a design for incorporating the HP-41CV in a convenient kneeboard format. Based on ideas and conversations with pilots from various aircraft communities, the design on the following pages is being submitted for consideration.

The design seeks to minimize size and weight, yet retain room to write on standard 5X8 cards issued by the ship for card-of-the-day purposes. The current design uses the standard issue kneeboard. The top was removed and raised by a spacer to accomodate the thickness dimension of the HP-41. A cutout in the top, left of center and aft, allows the calculator to be dropped into a sleeve. Velcro on the bottom of the calculator and on the sleeve holds the calculator in place. The sleeve is shaped to let the calculator face lie flush with the top face of the kneeboard.

The light assembly and lower clip have been removed. A separate clip board, purchased from a civilian source and slightly larger than 5X8, is attached with a hinge to the upper clip. A 5X8 paper pad will fit on the clip board, and a 3X5 paper pad, adjacent to the calculator, fits into the

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[20] Mr. Michael Herskovitz

upper clip. A small area immediately to the right of the calculator face could be used to tape a small reference card to enhance use of the calculator.

The next page shows construction details for the knee-board. The following pages are photographs of the kneeboard constructed by Aeronautical Engineering shop personnel at NPS. No provisions have been made for an integrated light. The lights that come with a kneeboard seldom work for an extended period; cockpit auxiliary lights should be sufficient for illumination.

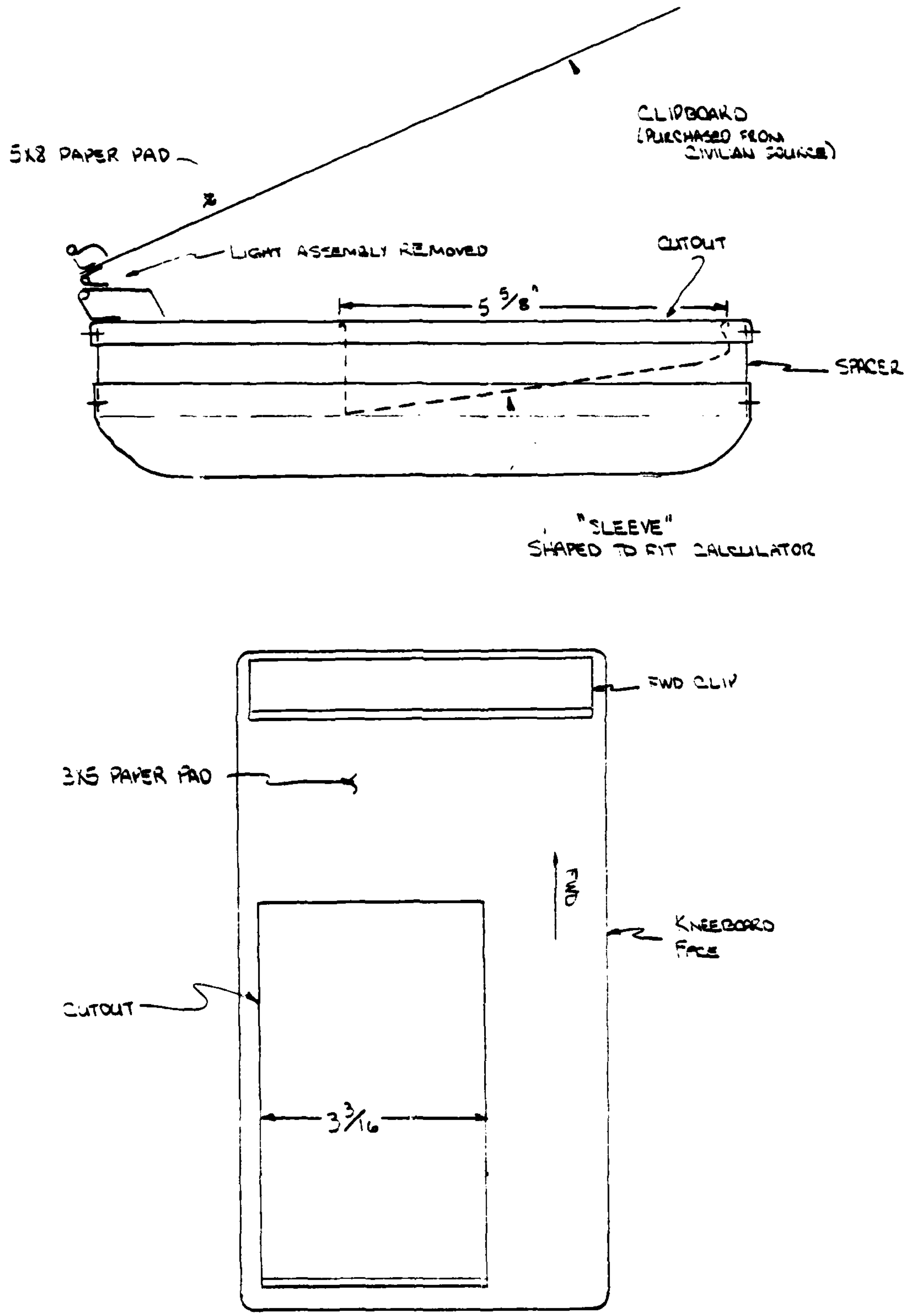

Figure 3: Kneeboard/HP-41CV Construction Details

Figure 4: Kneeboard/HP-41CV, Closed

Figure 5: Kneeboard/HP-41CV, Open

Chapter X

CONCLUSIONS AND RECOMMENDATIONS

A number of auxiliary topics were generated in the course of preparing this report. Many are outside the scope of this work but are included here for future reference.

10.1 CONCLUSIONS

1. The HP-41CV is currently one of the most advanced handheld programmable calculators available. There are, however, pocket sized computers that use microprocessor technology that should be examined for potential. Many are faster when accessing specific data, but they may be more difficult to learn and and to maintain in a squadron environment. Compliance with FCC regulations must also be confirmed for operation in aircraft.
2. The kneeboard/HP-41CV combination should alleviate problems and concerns generated with regards to additional loose items in the cockpit. Other communities interested in using the HP-41CV are encouraged to consider this or a similar kneeboard design.
3. The kneeboard may provide additional EMI protection for the HP-41CV in the E-2. Other agencies would have to conduct appropriate testing to confirm this, however.

4. The HP-41CV can be used by aircrew not familiar with the HP-41CV or handheld programmable calculators. However, at least one person per squadron should be thoroughly familiar with how the calculator works in order to maintain software and program status.

5. The potential to reduce fuel consumption in fleet aircraft is probably limited. The true benefit to having the capabilities represented by FPAS program is the ability to stretch out a critical situation, such as a low fuel state BINGO. The use of FPAS in conjunction with safety of flight programs such as BINGO will gain greater acceptance than as a fuel conservation aid.

6. During the EMI effects test flight, the original version of the E-2C FPAS contained readouts for fuel flow and horsepower to fly IAS. These values were found to be radically inaccurate, however, and the equations to generate those values have been eliminated from all three FPAS programs. The original purpose in including such calculations was to enable the pilot to calculate fuel, time and distance to go parameters. With a calculator handy, however, such parameters can easily be computed assuming the linear fuel consumption nature of the E-2 and C-2.

10.2 RECOMMENDATIONS

1. It is recommended that a validation of the programs in this report be undertaken. In that regard, research funds have been requested through NPS in order to purchase at least one more calculator and appropriate peripherals to support software and continuing research. Validation efforts will be conducted in cooperation with NADC.

2. If there is interest in the C-2 community in a validation effort, request they contact NADC or myself for assistance.

3. Consideration should be given to incorporating a validated suite of programs into a ROM chip obtained under contractural agreement with Hewlett-Packard.

4. Pending approval, or failing to approve, a ROM chip, consideration should be given to having program code converted to printed bar code for non-volatile storage. The ship environment may be too precarious for magcards to retain microcode accurately over an extended period of time on-board.

5. Upon incorporation of the HP-41CV into daily flight operations, at least one officer per squadron, preferably from the NATOPS Department, should be appointed to be in charge of coordinating the squadon's use of the calculator. Responsibilities would include loading and check-

ing of hardware, coordination of warranties/maintenance, and instruction of squadron aircrew in the use of the calculator.

6. Minimum E-2/C-2 squadron inventory of HP-41CV calculators and peripherals should include the following: four (4) HP-41CV calculators with one (1) Extended Functions/Memory module and two (2) Extended Memory modules per calculator; two (2) magnetic card readers; one (1) printer/plotter; and one (1) optical wand (assuming bar code is available).
7. Development of other programs to enhance safety of flight and fuel efficient operation should be researched and incorporated. The limitation on this effort, however, is the amount of memory space available in the calculator. This limitation is relieved if more than one calculator at a time can be used.
8. Request information be forwarded concerning the validity of using the current issue of the E-2B and C-2A NATOPS Manuals for FPAS and BINGO programs. If SOP or more current information is available, it should be incorporated.
9. Incorporate wind at altitude corrections into the E-2 and C-2 BINGO programs.
10. Research into designing the BINGO programs demonstrated that a microcomputer based BINGO program could be de-

signed for use by the ship to quickly plan the fuel required values for all airwing aircraft for each recovery. Such a program could, most importantly, incorporate adjustments to fuel required for forecast winds aloft. Quick access could also be obtained for various aircraft configurations determined by emergencies such as hydraulic failures.

Appendix A
DATA LOADING PROGRAM

The following is a code listing of a short program designed to load data in the HP-41CV registers. Indirect addressing is used so that registers beyond R99 can be loaded.

The program starts with R00 and loads sequentially in an interactive manner. Assignment of user labels is at the discretion of the user. The second half of the program can be used to read the contents of designated registers. The program can enter data starting with any register by carefully loading an address into the X register. Caution is urged to prevent overwriting old data or entry of data into the wrong location.

```
♦LBL "STO"
0
STO 00
♦LBL 01
"R="
ARCL 00
PROMPT
STO IND 00
1
ST+ 00
GTO 01
♦LBL "RCL"
0
STO 00
♦LBL 02
FIX 0
"R="
ARCL 00
PROMPT
FIX 3
RCL IND 00
STOP
1
ST+ 00
GTO 02
END
```

Appendix B

ADDRESSES

Persons interested in obtaining clarification of details in this report or who desire to pass on corrections can use the following addresses in the time frames indicated.

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October 1982 to March/April 1983

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Appendix C

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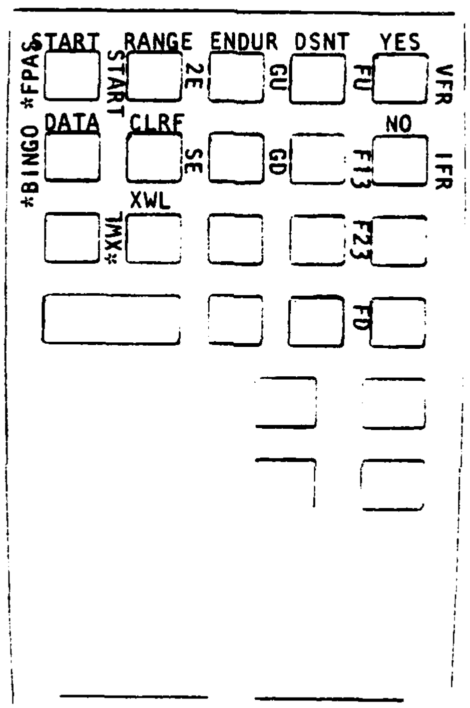

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